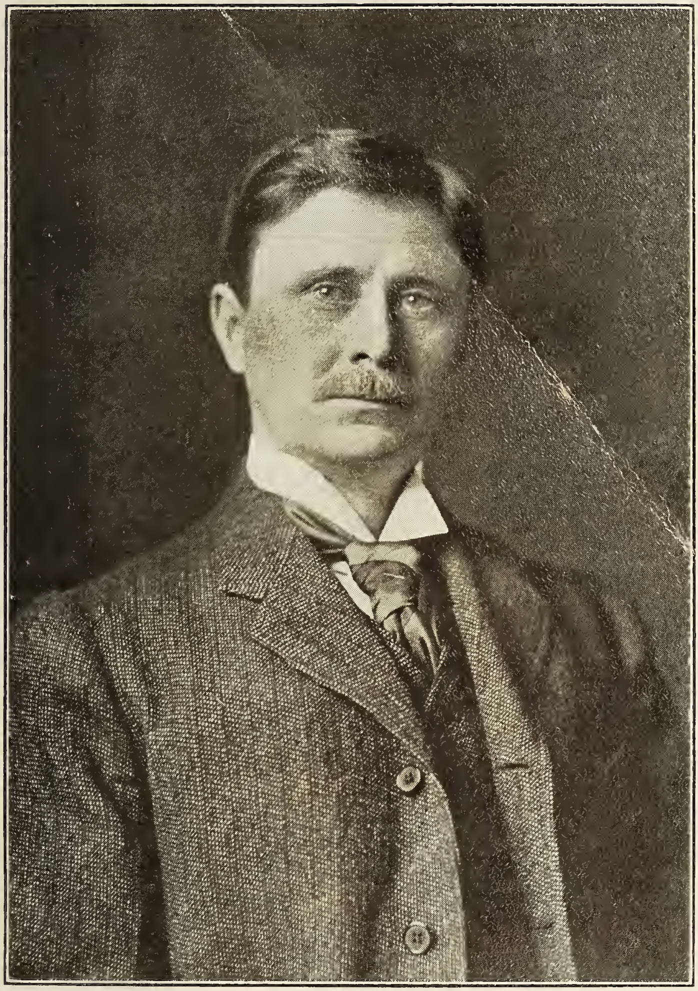
OLD SERIES VOLS. XXII & XXIII

NEW SERIES VOLS. II & III

Digitized by the Internet Archive
in 2017 with funding from
University of Toronto

https://archive.org/details/papersreadbefore1908scho



F. W. G. Haultain

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 NOVEMBER, 1908 New Series Vol. 2, No. 1

THE YOUNG GRADUATE AND THE PROFESSION OF MINING ENGINEERING*

H. E. T. HAULTAIN, C.E., Mem. Inst. Min. Met.**

Both in my own experience and in my observation of young graduates from engineering schools in all parts of the world, I have found a general ignorance of the profession as a whole, generally coupled with a very much distorted view of the young graduate's position in, and relation to, his profession. This is probably to a very large extent unavoidable, but it has always seemed to me a very important point, and I should strongly like to see a series of lectures on the subject embodied in the general curriculum of the school. Doubtless very much of such knowledge must be personally and painfully learned by experience, but a very valuable skeleton of information could be built up in the lecture room. In the short time at my disposal, I will attempt an outline of the profession of mining engineering as I in my limited experience have found it, and attempt to deal with some of the more prominent difficulties that will be encountered in the early days of the Young Engineer's career.

Kipling says:

> "When the waters were dried an' the earth did appear,
> The Lord, He created the Engineer."

And, from the first, the mining engineer must have been a man of prime importance in his class. As time went on, and all structues depended more and more, either in their fashioning or in their material, upon the supply of metals, so would the importance of the miner become greater. In France and Germany this is recognized, and mining engineering ranks ahead of all other branches of engineering, but in our English-speaking communities it is not officially accorded the same recognition, and possibly the miner is often considered rough and unfinished in his methods, a pioneer occupied in coping with nature in the rough and lagging far behind the polish and finish of the scientific engineering of the cities. It is true he is a pioneer and that he deals with the forces of nature in her crudest and roughest forms, but he does it with a wider range of scientific knowledge than that possessed by any of his engineering brothers. He needs and he makes use of the specialized knowledge of all other branches of engineering in addition to such that is peculiarly his own.

---

*An address delivered before the Engineering Society in 1902. This will be followed by an article, "The Mining Engineer and his Relation to the Public," with particular reference to Ontario.

**See Biography in Section 2, page 3.

The profession of mining engineering embodies very much more than any one man's mind could possibly encompass, and there is a limitless number of subdivisions or combinations of subdivisions for the specialist in which to bury himself.

In general, mining engineers are divided into two main classes, viz., Mining Engineers and Metallurgical Engineers. Under this classification in its closest sense, the mining engineer has to do with the getting of ore to the point where it lies in a broken state at the surface, and the metallurgical engineer carries on the work from this point until the metals are finally extracted from the ore. But as a general rule the metallurgical engineer's work is confined to smelting operations, while the processes of mechanical concentration of ores, and even the leaching and lixiviation processes are in the hands of the mining engineer in charge of the other mining work. The reason of this is to be found in the fact that as a rule the mechanical concentration and lixiviation of ores is carried on at the mines under the one management; while smelting is generally done at some central point at a distance from the mining operations. The department of smelting I must leave out of consideration, and trust some other graduate will take up this very important branch.

Of mining engineers proper, there is a rough classification that will divide them into two classes: the engineers connected with the large permanent mining centres, usually coal and iron; and those connected with the general mining industry scattered all over the world. It is with the work of the latter class that my experience has been and it is with them that I will deal. This class of mining engineers is again subdivided into two main classes—the consulting engineer and the managing engineer, and the thoroughly competent consulting engineer will have passed through the stage of managing engineer. The work of the consulting engineer can be divided into two main divisions—reporting on the value of properties and reporting on the management of properties. The term managing engineer would embody in its general sense all the engineers resident about a mine, and would include assayers, chemists, surveyors, mechanical engineers, electricians and those engineers skilled in concentration and lixiviation processes.

The prominent consulting engineer would have his headquarters at some commercial centre—London being the particular home of this class—and he might or might not have assistants or partners in parts of the world nearer to the mining centres. A large part of his work—perhaps his sole work—would be the examining of and reporting on, the value of mining properties in various parts of the world. This is of course most important work and is correspondingly paid for. In this work experience and judgment, built upon a foundation of wide scientific knowledge, coupled with a well balanced commercial sense and the necessarily ever present disinterested integrity, are the main requirements. It is a position of the utmost commercial responsibility, a single report often controlling the investment of millions. The keynote of success is of course Reputation, and before a man could expect to succeed at this work, he must have built up a reputation, and have made friends. The fees for this kind of work are high. Among prominent London engineers the fee for a report of any consequence would not often be under $5,000.

Consulting engineers located in either commercial or mining centres also undertake the reporting on the management of mines. They may visit the mine at intervals, or they may simply base their reports and advice on the information, accounts, etc., supplied to the company by the mine manager; and their advice might extend to the supplying of detailed plans for development or for machinery. Consulting engineers in this capacity are frequently engaged by London companies owning mines abroad.

The position of consulting engineer, with a reputation, able practically to choose his own work, travelling in many parts of the world, returning always to his headquarters, and receiving most substantial fees, is a most enviable one, and is one looked forward to as a natural consequence of years of successful work in the field.

But it is to the position of managing engineer, and the steps subordinate to that position that I would more particularly draw your attention. Perhaps I could not do better than outline the duties and responsibilities in an actual case.

Take the case of the manager of an English Company owning mining territory in Africa. They have one mine partially developed and several prospects giving more or less promise of good values. This Company is managed in London by a board of directors—non-technical men—with a chairman at their head. This Board will meet once a month, or once a fortnight, and will outline the general policy of the Company. The details as far as the London end is concerned are in the hands of the chairman, who relegates them largely to the secretary, who corresponds with the manager in Africa. The manager will have a wholesale power of attorney to do anything and everything in Africa, and will be answerable for all his actions directly to the Board. He will have an agreement or engagement as manager, terminable as a rule by six months notice on either side. He must of necessity have had the full confidence of the

Board before he was apppointed, and must retain this to the full or his position will become untenable. The Board will be completely at the mercy of the manager—their only information being what he chooses to give them in his letters and reports, together with that obtained through an annual visit of a director or a consulting engineer. The manager in turn will be very much at the mercy of the misunderstandings and disappointments of the Board, and nothing but full confidence can keep things running. The keeping of the Board well and judiciously supplied with information is perhaps one of the most important functions of the manager.

Coming nearer to his work, we find him in charge of an isolated community twenty miles or more from a settlement—100 miles from a railway—with slow-going ox-wagons as the only means of freight transport.

First and foremost he must examine his ore deposits and then with all the knowledge that he possesses of geology and minerology, he must form some opinion of their probable value and outline a method of development. With his already partially developed ore deposit, all his past experience of the costs of mining and ore treatment, together with all the information he can obtain in a raw country concerning labor, power, fuel, transportation and markets, will leave him in no high degree of certainty as to probable profits. He has to study the resources of the country, and to design his plant accordingly. He is alone, single-handed, and up against the real thing. And he has to organize in a bare wilderness a large and complex business. While keeping his mind keenly on the deep scientific problems of the various and varying ore deposits, on the problems of haulage, timbering and ore treatment, he has to arrange for the establishing of his camp, the housing of his men and animals, the purchase of innumerable supplies and transportation over difficult country. He has to procure, and very often to a large extent must be prepared to train, a most varied gang of workmen, skilled and unskilled, in all branches of labour. He has to control a most mixed lot of the roughest class of men, both white and black ; at all times he must preserve his personal influence and tone. He is the single-handed autocrat of an isolated community, with nothing to maintain his authority but his own personality. He is spending large sums of money, and spending it in innumerable ways that are difficult to trace and check. On all sides are men trying to get the best of him in every proposition, and he must have the business side—the commercial side—of his work organized to a degree unthought of in many establishments nearer the centres of civilization.

While organizing and personally controlling these varied complexities, he must ever keep a clear mind for the constant, careful and well balanced study of the intricate scientific problems of his work.

Let us consider some of these engineering problems.

In the first place his ore bodies differ in many respects from any he has had any previous knowledge of—no two ore bodies are the same. Nothing but experience—wide and varied experience—founded on scientific training, is going to save him in the solution of the problems involved in the exploration of his ore bodies.

He has one ore body so far opened up that sufficient values are in sight to justify the installation of machinery on a large scale for the breaking, mining and treating of his ore. Upon all the intricate details I cannot touch, but let us look at some of the main problems involved.

The first problem of mining his ore and protecting his underground workings is one depending almost entirely upon judgment and foresight based on experience, and is one that no amount of training or reading can solve for him. In any case he must work tentatively—must feel his way. That probably is the keynote of all underground work—certainly of all the early stages. It is impossible to see far ahead, and one must feel his way foot by foot—planning tomorrow's work by today's results.

But the planning of the ultimate development which must soon be taken in hand is a large problem involving work spread over many years, and the general skeleton of the plan must be laid out and undertaken at once. Upon the position of the main working shaft or tunnel the position of his surface works will to a large extent depend. Into this problem must enter the problems of pumping, ventilation and haulage, and much calculation and well balanced judgment are required for a satisfactory solution. The problem involves not only a very large sum in itself, but will always very seriously affect the working costs.

Inseparable from this problem is the question of power. The case I have in view has practically unlimited water power five miles away, so that the question of power does not affect the hoisting question; and it is found that for the first few years the most satisfactory course is the running of a low level tunnel which will give several years ore supplies above it, and which will always be the main working tunnel.

The next problem is the treatment of the ore, and though the manager ought to be capable of dealing with this problem himself, he may call in the assistance of a consulting specialist.

And here comes in a very nice point:

It is of course out of the question that our mine manager should know everything, or that he should know as much of detail as a specialist in any branch, and very naturally the average business man will say: Here is an isolated problem, let it be solved by the specialist.

In the large mining centres are to be found consulting engineers, who are disinterested specialists in milling and lixiviation processes, and who make a business of such problems. They often are called upon to supply complete plans.

In the first place, there is one statement that will hold under all circumstances:—There is no isolated problem connected with any mine. The mine and everything connected with it is one vast complex machine, with all its parts and details interdependent, and smooth running—successful running—depends on the balance between all its parts, and upon their perfect interworking. This can only be achieved in one mind. There can only be one controlling hand, and though it is not necessary for the manager to design all the details, he must fully grasp the essentials of every department. He must be responsible for everything.

If outside consulting advice is called in, it must be in consultation with the manager, and if the manager is incapable of dealing with the subject, a most dangerous element of failure is at once introduced. This is a most essential element of mine management, and I will refer to it later on.

If a thorough professional consulting engineer with a reputation is called in to settle the problem of ore treatment, he may be prepared to deal with it in its entirety, in which case he would go carefully into all the conditions surrounding the problem from the ore deposit to the market, and would do this in close consultation with the manager, whom also he would carefully consider as an important condition. Then after designing the plant he would to a certain extent supervise construction, and on its completion would personally attend to the early stages of its operation. For an ore treatment plant is not like a small steam engine which will run when supplied with steam. Even after most careful and capable designing, there will have to be much adjusting of its method of operations before the best results are obtainable, and this adjusting must be done by a capable and responsible head.

If the specialist's connection ceases on the delivery of the plans, the manager's responsibility will only then commence, and if there be any failure in results the manager will blame the design and the designer will blame the method of operation, and the company will be in the position of the man trying to sit on two chairs. This is one of the commonest causes of failure and trouble in mining, and every mining man can point to many incidents of this kind.

In the case I have described the specialist's fee would be enormous—probably much larger than the manager's annual salary.

Most frequently it would not be possible to obtain the services of a distinguished specialist and recourse is often had to the manufacturers of mining machinery. They call themselves specialists in such matters and very often are so, and have much experience and data at their command, but we then have the anomalous position of the consulting engineer and the contractor being one and the same person. It is surprising how frequently this is the case, and it is not surprising that this is most frequently a cause of disaster.

The manufacturer can never be a disinterested party. Conditions do not permit him to make a thorough examination of all the conditions. He will tell you what machinery to put in; it will be his own, and there will be as much as possible of it; it will be good machinery, and he will guarantee the smooth running of individual machines, but he will not guarantee the results. And he will have many excuses to show that the blame of failure is not attachable to him. He will tell you that the ore treated in the mill differs from the sample sent him; that the construction was poor and the operation is worse. You cannot pin down the manufacturer to results—he is too old a bird at the game.

What then is the manager to do?

He ought to be capable of designing his own plant. If he feels doubt about it, let him engage a man who has knowledge of such matters, engage him as an assistant—as a head of a department—and let this man experiment on a laboratory scale in co-operation with the manager.

After the manager, with or without outside aid, has decided that his ore is a free milling ore requiring a subsequent treatment of tailings by cyanide, and has decided on the general main idea of his plant, he can safely go to the manufacturer for his machinery, trusting largely to him for all details—for the details are the work of a mechanical engineer, and in this department the manufacturer is the highest specialist.

The first plant will doubtless be a small one, designed with a view to further increase, and also with a view of permitting considerable experimenting.

What I have said in regard to the ore treatment plant also holds good with the tramway from the mine to the mill, and with the water power plant, and with the electric transmission plant, with of course some modifications.

Aerial tramways come nearer to being isolated problems than does any other part of the plant, and they are very frequently given over to contractors, who guarantee to erect the tramway and run it for a short time. To a certain extent the tramway can be looked upon as an isolated machine of the nature of a steam engine. But again to make the contractor and the consulting engineer the same person, even in so simple a matter as a tramway, tends to an unnecessary waste of money and consists in paying to a contractor very much more than what is already paid to the manager or his staff for the same work.

In the case of electric machinery—electricity is perhaps somewhat removed from the mining engineer, but is daily becoming less so, and though the mining engineer would certainly never attempt to design his dynamos, he certainly ought to know enough to decide whether he wanted direct current or alternating machinery, and to be able rationally to check over the electrician's figures as to line loss, etc., etc.

To sum up this question of machinery, the manager should be thoroughly conversant with all the standard types of machinery of all the prominent manufacturers that might possibly be of use in mining work, and this includes practically everything except heavy ordnance and marine engines. With the detailed design of this machinery he need not unduly burden himself beyond understanding the why and the wherefore of every part. The manufacturer can be depended on for excellence of detail. Thereon depends his existence.

The erection of his plant is an all-important part of the manager's work or of a most trusted assistant. To let this by contracts generally ends in disaster unless most competent and keen watch is kept on the contractor. Generally speaking, in all mining construction, it is more satisfactory and more economical to watch over a good foreman than to check a contractor. The contractor, like the Indian, will be bad if he can be.

The operation of the plant will be the work of the heads of departments, always under the personal eye of the manager.

This is a bare skeleton of the work of the mine. It is filled in with an interesting network of details of every kind, from the niceties of subtle chemical investigation to the handling of a drunken mob, and through it all must run side by side the deepest scientific thought and the most cold-blooded business methods, tempered always by the truest disinterested professional tone.

The manager will have to assist him at his work, besides his own personal assistant, several heads of departments—a commercial superintendent in charge of the buying and of the books and the commercial side of the business generally; a surveyor, an assayer, superintendents or head foremen of mine, mill and cyanide plant, a master mechanic, and foremen of the various subdepartments, and with these the successful manager will keep in very close, intimate touch.

There is another phase of the manager's work that I have not yet touched upon—a department in which he remains alone.

The mine is the property of a company, and the public pay very much more attention to the shares than they do to the mine, and the majority of shareholders expect to make very much more out of the fluctuation in the price of shares than they do out of the mine. There is a constant active buying and selling of shares. Now the manager's regular reports to his Board can very materially affect the price of shares, and his plans of operations do also very materially affect the price of shares; discoveries will be made in the mine that will make enormous differences in the value of the stock. In very many ways the manager has a very large control over the price of the stock, and if there be any deviation on his part from strict honesty, from the true professional spirit of disinterestedness, he may be in a position to make much money for himself or his friends. Here is a wide open temptation—a temptation so coarse and glaring—so palpable—that it will in general be easily avoided, but it has also its more subtle aspects, and the only protection a man has lies in the inherent honesty, the professional spirit and the tone of the true engineer.

This is an outline of the position of a manager of by no means large property, and may be taken as a fair general example.

As an example of the extent to which the business of mine management may grow, I would cite the case of The Consolidated Gold Fields of South Africa. In 1897, in their engineering offices in Johannesburg, they had fifteen draughtsmen in the surveying department, and seventeen more in the general department. Their chief engineer drew a salary of $60,000 a year, their chief mechanical engineer drew $25,000, and so on. Of course this office did all the engineering work for a large group of mines.

But it is the smaller propositions that tax the resources of the mining engineer most severely, for in these cases he must himself control every department, and must carry out works that in larger concerns would be in the hands of heads of departments in themselves specialists capable of carrying responsibility.

In an examination of the duties of mine manager, as I have outlined, what do we find as the more prominent points? I think that we shall find that the most important point of all is confidence—mutual confidence between the directors and the manager. To obtain this the manager must be a man of experience—a man with a record—a man who has made friends. The next point of importance is the fact that the whole concern, first, last and all the time, is a business proposition undertaken with the sole and only purpose of making money, and as far as our engineer is concerned, making money legitimately, though—and this is a point ever to be remembered by the young graduate—there are always those seeking to make money illegitimately. The whole concern in every department must be organized on a commercial basis. The third point of importance is the essentially scientific character of all the problems involved in the finding, winning and treating of the ore. In the young graduate's technical course, his whole time and energies being occupied with this latter point, he is apt to lose sight almost altogether of the other two. But these three points are as inseparable as the three dimensions of space, and any proposition founded on two only will be a failure.

Of course there is an exception to this rule—the factor known as luck may upset all rational conceptions.

Besides these three fundamental points there are others of nearly equal importance. All mining work is new work; every problem is a new one, differing in many respects from the engineer's previous experience; every problem is complex, involving a large number of facts and conditions often very obscure. The engineer must be a man of varied experience, not only conversant with a wide range of scientific knowledge, but with a very wide range of actual experience. He must be essentially quick witted and he must have a lively technical imagination, ever ready to imagine new combinations and possibilities. But his temperament and technical character must be strong enough to allow this imagination full play, without it carrying him off his feet into a wilderness of conjecture.

He must be physically strong—able to live anywhere and eat anything; he must ever be ready to pack his blankets and his scientific knowledge on his own back.

He must be a professional man in the fullest sense of the term. He must have tone; I cannot define tone, it marks quality, or shall I say quality marks tone. And tone is as unassailable as it is hard to define. From the first step to the last the mining engineer is surrounded by temptations of every kind; every tendency within him will have free opportunity to pull him towards disaster. From the start he is away from the influence of custom and social ties, and he who has never been absolutely free from these influences can have little conception of the extent of their controlling power. But the temptations arising from avarice and ambition are the most continually and persistently present. And these temptations are often of the subtlest kind—most frequently not having even the appearances of temptation, and this is a phase of his work in which the engineer stands alone—a game in which he must play a lone hand.

Disinterestedness is the foundation and skeleton framework of the whole structure of the professional man. If he is not disinterested he is nothing. He is an employee and his interests always must be on behalf of his employer. This explains how the mine manager can be a business man and still a professional man. He is carrying on business for another and he can carry it on only in the cleanest and straightest of business methods.

Another thing to be observed in the work of our mine manager is that he has more to do with human nature than with any of the other forces of nature. He has to deal with his directors on one hand, and with his employees with the other. He has to deal continually with the cleverest scoundrels and rogues of all classes and kinds. He has to depend on his judgment of character in black, red, yellow and white.

Well, gentlemen, have I painted an impossible picture for you? I have outlined the main skeleton frame of a possible structure—a structure for which there is an enormous demand; the completion of the edifice depends upon the individual.

So much for what there is in front of us. Let us now consider our first steps.

The young graduate, despite his hard work and scientific attainments, is, as an engineer, well nigh as useless as the newborn babe. I know you will not believe this—it is not compatible with your years and your efforts—it is probably just as well that you don't believe it, but it is one of the first important things that you must learn in the outside world.

How is this so? Thus: the young graduate has had no experience (I know there are exceptions), consequently can have no judgment, and therefore is absolutely incapable of responsible initiative.

Many people will tell me I am entirely wrong—that the young graduate is full to overflowing with judgment—that he will judge anything or anybody, and as for initiative, he has the nerve and the supreme self-confidence to tackle any proposition—to initiate anything. Exactly—that emphasises what I mean—he has no judgment—that is, no judgment that can be depended upon.

In England they put the embryo engineer in an incubator—that is—he is articled as a pupil for one, two or more years to an engineer of standing and experience, and for this privilege he will pay as much as $1,000 a year, and will receive no pay of any kind in return for his work. With this idea I would be wholly in accord, if the conditions in the colonies permitted it. I would not advise for a colonial mining graduate an articled pupilage in England; but if a western mining engineer would take him, he could not possibly do better. But out here the conditions are different, and we have to face conditions as we find them.

In the first place, many of our technical graduates have not the means to pay any pupilage fees, nor even to give their services and time for nothing; they must earn soon after graduation. And again I do not think you could persuade any mining engineer in active work on this continent to accept pupilage fees or to have about him a pupil working for nothing.

The young graduate must earn money, and it is a function of the technical school to leave him in a position to do this, and there are two or perhaps three or even four branches of work in which the technical schools can turn out commercially useful men. I refer to assaying and surveying, and to a certain extent, draughting.

The school can—if it chooses—turn out men who could take hold of the position of assayer or of surveyor at any small mine, or who would make excellent assistants on a large property. These positions require practically no judgment or initiative, and the main difference between the work at the school and the work at the mine consists in the rapidity that is required in commercial work, and a certain ability to make shift with the anything but ideal conditions and appliances that one may be up against. If to a smooth working knowledge of assaying and surveying, the young graduate has added an active knowledge of bookkeeping and cost-keeping, he has three strings to his bow that will earn him a living in any active mining camp.

It is a common saying in the West that if you cannot get one job you should take two, by which is meant that you may often be able to get a job as an assayer and bookkeeper combined where you could get nothing if you applied for either singly. My advice to any technical school would be—make bookkeeping and cost-keeping and the commercial organization of engineering business, an important part of your curriculum. My advice to any student of a school where this is not part of the curriculum is, to take steps to make a special study of these subjects at the earliest possible opportunity.

The obtaining of a position as assayer or surveyor, and, from that position, studying the actual working conditions of a mine, to be ready for further advancement in your profession, is the orthodox method.

The surveyor has the better opportunity— he is here, there and everywhere on the property—mixed with everybody and sees everything that is going on, and will be more naturally given the position of acting manager or assistant manager.

However, before going any further, let us consider more fully the functions of the first few years after graduation. The first function doubtless is the earning of a living, and the orthodox way of doing this I have outlined. But if you stop at that, you will never be an engineer. The main function is to get experience—wide, varied experience—of everything you will need in after years. Another function is to make professional friends, but the main point is experience.

In your S. P. S. course you have had a most excellent training. You have been trained to think—to reason—to read and to a certain extent to observe—you have been trained to ask the question " why" and to make an effort to rationally answer that question. You have learnt much about the physical laws underlying all engineering problems. The excavations have been dug and a very substantial foundation has been laid for a very elaborate superstructure; and further than this, the skeleton steel frame work has been in part erected; and even still further, if the material for further erection has not been gathered, the method of obtaining it has at least been indicated. You can live in the cellar if you like, but that will never make a house of it—you will never be an engineer. You must build on the foundation. You must fill in the skeleton frame work —you must erect extensions to your frame work—this you must do alone. Nobody else can do it for you. The elaborating of the structure is by personal experience. In my student days Prof. Galbraith advised us to devote the first ten years after graduating to the sole function of gaining a varied experience. I think this most excellent advice. No matter what position you hold you will be gaining experience, and to gain a varied experience you must not stay too long in one position. But you must not trust to haphazard luck in the positions you get. There are several points to be remembered. In the first place in your early days you can do things that later on in your professional life, you could not do. For instance, on graduating you could work as a mucker or common laborer underground—or you might innocently be employed by some notoriously corrupt men or companies. In neither case would your reputation suffer, and you would be the gainer by some valuable knowledge.

The most prominent feature of mining work in all parts of the world (and in Canada and Ontario have we had most scandalous examples of it) is the extreme corruption, crookedness and dishonesty that frequently accompanies it. This exists to a degree beyond all conception by those who have not actually seen it. If you keep this fact in view and remain always ready to quit a job when it looks dirty, you can in your early years take pretty nearly anything you can get, but later on you must be more careful what you do. Then the main point would be to get near good men, near good companies and successful concerns.

In your early years there are several very unorthodox things that I would advise. In all mining work the biggest item is for labor, and there is no other item of expenditure in which money may be lost or saved to the same extent. The human machine is not only the most used, but it is the most complex, and to be a successful mining man you must understand your workman. The best place to study your workingman is alongside of him. I strongly advise every young mining graduate to work as a mucker or trammer underground in some fairly large mine. To do this properly you must do it thoroughly and drop all your engineering business, and your diploma and all that, and get into dirty overalls and get your job from the foreman and sleep in the bunk-house and keep away from the office. This I know is often advised, and in Cornwall and Freiberg there are regular practical courses underground where the students play more or less seriously at work, and learn after a fashion to swing a hammer and frame a set. Candidly I don't think much of that—I do not see that such work is of very much use, and in those practical courses you don't learn anything of the men—you don't get round to their point of view. This to my mind is the essential point, and my advice is to get a mucker's job and hold it at least over one pay day and over several if you can. It will hurt and it will be hard, but it will be worth it.

Again, if you have any inclination towards carpenter's work or machine fitting or any opportunity to follow up such work, I say by all means do so. I know of no better qualification for a young man seeking mining experience than a knowledge of machine fitting. There is no part of a mine free from machinery, and the fitter is wanted everywhere and gets a job more easily than any other class of skilled or semi-skilled workman; while a carpenter can often get a job on mill construction or the like that will give him an insight into construction that he could get in no other way. These are not short cuts to success or by-paths—they are stepping stones and most valuable ones at that. I would strongly advise the mining student to spend at least one of his summers in a machine shop or in a carpenter's shop. I would consider this better than a summer spent in an assay office, on survey, or in a mine.

The next question is as to where the young graduate is to go on graduation. Into the question of a post-graduate course I cannot go beyond saying that I am in favor of a post-graduate course, and would still recommend Freiberg despite all the advances made by technical schools on this continent.

After the completion of his technical course he should go to some active mining camp, and I certainly would choose the Western States. I am enthusiastically a Canadian, but I do not advise the young mining engineer to remain in Canada. He should go to an older mining country for his experience, and the United States—the Western States—has trained and still is training the world's most prominent engineers. And when you go west leave your diploma behind you, also your testimonials and recommendations. You will be looking only for subordinate positions, and for these positions men will size you up by looking at you and will discharge you as casually as they engage you. Never be afraid of quitting a job. It is no disgrace—very often it is not a bad thing to be discharged. A willingness to turn your hand to anything and everything that comes your way and do it with your best effort, are traits that will help you more than others. It will be several years before you get to what your heart pines for—that is real engineering work—but you must not neglect it for that reason; your eyes must always be open to everything about you, and you must read everything you can lay your hands on—technical magazines and catalogues in particular.

You will probably find the life a hard one, full of painful physical effort—full of misunderstandings and disappointments. Hope will be long deferred. Your scientific attainments will seem lost—swallowed up by chance and the force of circumstances. You will think you are losing all your finer feelings—your social niceties; the latest operas and plays will hardly be known by name to you and the popular airs will be three years old when they reach you. Life will be anything but a soft snap and your only consolation will often be: "Well, it's good experience, and anyway, it's all in the day's work!" You will find that you will have to give up very much, if not all that went to make life pleasant, and you will get in return—if you are lucky—work —and in many years—if you are lucky—well paid work.

But you will see—and if your eyes are open, life will be very full—you will play your own game with a freedom and a scope unknown in any other profession. You will have opportunities to carry your tendencies to the full. You will be with men and you will work with men, and the conditions and surroundings will be such as to bring out, in full prominence, the characters good and bad of men. Veneer and polish will be absent, and if you are a lover of men you will love your life. If you want an easy life leave mining alone. If you are not a tramp and want everything settled—if you are contemplating early marriage—don't go in for mining, for you will have to live and work where it would not be fair to take her.

PRELIMINARY STUDIES IN CONNECTION WITH THE DEVELOPMENT OF HYDRAULIC POWER

H. G. ACRES, '03

It is not within the scope of this article to fully discuss such a subject as this, as every hydraulic problem involves features peculiar to itself, which require special study and treatment. For this reason it will be necessary to make certain assumptions and follow out a line of reasoning based upon them.

Assuming, therefore, the existence of a stream upon which, at one or more points, power development is structurally and economically feasible, the first point to note is that the very fact of development being economically feasible implies the existence of a market for the power output, or at least the certainty of establishing one within a reasonable time. So that before the hydraulic features of the problem are considered in detail, the commercial possibilities must first be studied with a view to ascertaining whether or not there is sufficient inducement offered to proceed with development.

The character of the market available to any source of power will vary widely with its geographical situation. In some localities the power output of the plant will be disposed of at the turbine-shaft, as is generally the case in the manufacture of pulp, lumber, flour, etc. In other localities it may be necessary to transform the mechanical output into electrical energy to meet the requirements of the market.

In the first case the problem is a comparatively simple one, it being simply necessary, in the majority of cases, to instal sufficient hydraulic capacity to meet a steady demand for power, the amount of which can be very closely estimated. In the second case, however, owing to the wide range of industrial uses to which hydraulic energy can be electrically applied, the question becomes much more complex, and for its proper study requires careful investigation and the exercise of conservative judgment, for the conclusions arrived at will have an important bearing upon the general design and lay-out of the plant and perhaps also upon its location, where more than one site is available.

The topographical features of the power site and the conditions of flow will of course be the main consideration in connection with the method of development, and will determine the limiting capacity. Apart from this, in so far, at least, as the installed capacity is concerned, deductions derived from a study of the market will be the controlling factor. It is to be noted in this connection that estimates of required capacity should not be based upon the lump sum of all contracts entered into or in sight, but upon estimates derived from a classification of these contracts according to the hours of service called for. It will then be possible to arrive at an approximation of the installed capacity required to handle the peak load, this being the value which obtains when the simultaneous demands of the power-users become a maximum.

An estimate of the average load can also be approximated, and from this an idea can be formed as to the proper capacity of the individual units to be installed, with a view to handling the variations of load with a maximum of efficiency.

This may be summed up by stating that for a maximum of operating efficiency, the lay-out of the plant and the individual capacity of the units will depend upon the load-factor, which is the ratio between the maximum and the average load; thus in the general case a small load-factor will call for individual units of small capacity, and as the load-factor approaches unity a smaller number of units having larger capacity will give the best economy. It is to be noted in the latter case, however, that where continuity of service is of first importance, the concentration of capacity may make the installation of a spare unit necessary.

A general investigation having established the fact that a suitable market is available, the hydraulic features of the problem may then be taken up in detail. The first point to be considered in this connection is the amount of water available, and a reconnaissance survey should be made of the watershed from which the supply is drawn. In this way information will be obtained as to the area of the watershed, the gradient of the stream, and general topographical features, such as the nature of the soil, amount of wooded and cultivated land, and the number and extent of lakes, marshes, etc.

An approximation close enough for practical purposes can usually be arrived at with reference to the area of the watershed from existing maps of the district. In Canada the Geological Survey maps answer very well, especially in the unsurveyed districts, as they are fairly accurate and contain a considerable amount of detail. The standard topographical maps published at Ottawa under the direction of the Dominion Geographer are still better, but these maps so far embrace a comparatively small area. Both classes of maps are plotted to a four-mile scale and notes can conveniently be made upon them in the field.

During reconnaissance particular attention should be paid to the possibilities of artificial storage along, or at the headwaters of the stream. Owing to the fact that the quantity of continuous twenty-four hour power available per foot of head depends upon the amount of water discharged under conditions of minimum flow, any steady increment which can be added to the minimum flow will increase the continuous twenty-four hour capacity in the direct proportion; and, if the maximum available head at the power-site has been utilized, and the market has absorbed the continuous capacity derived from minimum flow, the only way of "hydraulicly" meeting any further demand for continuous power is to augment in some way the natural low-water flow. This is generally accomplished by improving the natural storage facilities of the watershed, and, as before stated this is one of the most important points upon which information is to be obtained during reconnaissance.

The field work in this connection consists in collecting information as to the area of the various lakes and other adaptable storage basins above the site of development. Lake outlets should be carefully examined with a view to obtaining suitable cross-sections for damming, the topographical advantages of these locations being offset against the possible liability to land damages resulting from the construction of dams. If the watershed contains much cultivated land and the scheme of development is at all extensive or elaborate, all these storage basins should be traversed, dam-sites cross-sectioned and flood contours established. This will furnish sufficient information to establish the location, method of construction and extent of storage works and to admit the computation of flooded areas. To supplement this, data should also be obtained from the nearest weather station concerning the value of the mean annual precipitation, snow being reduced to water, and also the value of the mean annual temperature. It is well to get these records for as many years back as they extend. Empirical formulae giving a value for annual evaporation have been derived which involve the values of mean annual precipitation and temperature, but they are not safely applicable in a general way, owing to the fact that the constants involved have been based upon local data. Generally all that can be done is to obtain from the yearly records the minimum value of mean annual precipitation. This value, used in conjunction with the area, will give the probable minimum value of the total annual precipitation over the watershed.

From data collected during reconnaissance it will now be possible to assume a value for the "run-off" factor by which is meant the percentage of total annual precipitation which will be available for power purposes after allowance has been made for dissipation by evaporation, seepage, and the requirements of vegetation. This quantity varies widely with the locality and depends largely upon climatic conditions but also upon the topographical features of the watershed and the gradient of the stream; thus, in a watershed containing a large proportion of cleared and cultivated land with small lake areas and steep stream gradient, maximum values of the run-off factor would obtain, owing to the fact that a large portion of the precipitation would be carried off by freshets, while it would tend toward a minimum in the case of a sluggish stream draining a watershed containing a large proportion of open hard-wood forest and large lake area, these conditions tending toward a maximum of evaporation and seepage, and absorption by vegetation. The value of this run-off factor is generally from 30 to 60 per cent., but it often runs below 30 and sometimes reaches a value of 80 per cent. in the case of short mountain streams.

In Ontario the rivers tributary to the Lower Lakes will probably deliver 25 to 50 per cent. of annual precipitation, while those tributary to Lake Huron and Lake Superior and throughout New Ontario generally will deliver 40 to 60 per cent., some of the shorter and more turbulent rivers probably running as high as 70 per cent. The higher values are assigned to the northern rivers chiefly because their watersheds are largely covered by evergreen forest, which protects the ground surface from the sun and wind.

It should be noted that this exceedingly approximate method of estimating run-off is permissable only when it is impossible to obtain more exact data or in cases where the minimum natural flow is known to be sufficient to abundantly cover all estimates of market requirement. This applies only to rivers like the St. Lawrence and the Niagara.

In most cases, however, although such an estimate may be made valuable by the exercise of experienced judgment, it is necessary to supplement it with data derived from direct and frequent measurements of discharge. Too much stress cannot be laid upon the importance of this phase of the investigation and any appropriation reserved for its furtherance in the consideration of a power scheme can be well and profitably applied. The more frequently these gaugings can be made the better, once a week at least, and for a period extending at least over one cycle of the water year.

Extract from Water Supply and Irrigation Paper No. 80, U. S. Geological Survey, by G. W. Rafter:

"The writer has found it very convenient to divide rainfall and run-off records into three periods, those of Storage, Growing and Replenishing, with a water year beginning December 1 and ending November 30. The storage period includes the months from December to May inclusive, during which the evaporation and absorption by plants is relatively slight, and a very large proportion of the rainfall appears in the streams.

"The growing period, June to August, inclusive, includes the period of active vegetation, when evaporation and absorption by plants is most notable. During this period frequently not more than 0.1 of the rainfall appears in the streams, and sometimes not more than 0.05 and even less. Ground water tends to become lower and lower during this period, unless the rainfall is much higher than the average.

"In the replenishing period, September to November inclusive, with the normal rainfall, ground water tends to recover, and the run-off is larger than in the preceding period. This period is replenishing in that there is a tendency to return to normal conditions."

Records thus obtained will furnish evidence in connection with two conditions of outstanding importance; namely, the minimum and the maximum flow. From the first, the minimum continuous power per foot of head can be deduced, while the second forms a basis for the design of permanent works and computations with reference to overflow and sluiceway discharge area. Also, these with the intermediate values of discharge, will make it possible to calculate the amount of the annual run-off without assuming a value for the run-off factor.

As to methods of discharge measurement, that of the current-meter only will be discussed, as, with proper management, this is the most accurate, satisfactory and generally applicable of all, and the following is based upon the assumption that a current-meter will be used.

The best time to locate a gauging station is during the period of low water, because a stretch of river that may have a very appreciable current at high stages may become a quiet pond during the low-water period. For this reason, it is well if possible to establish the gauging cross-section somewhere near the head of a flat rapid, above rough water, where there will be a measurable velocity at all stages of flow. Moreover, a cross-section like this usually has the advantage of being more or less permanent, as it will have a rocky or gravelly bottom which will not be materially affected by floods.

Having decided on the gauging section, the establishment of a gauge for recording water-levels is the next step. This gauge should be set with reference to a bench-mark well out of reach of flood-water, so that if the gauge is destroyed by flood or other means, it can be replaced without affecting the relation of subsequent readings to those taken from the old gauge.

Soundings may be most conveniently taken, on a river of moderate size, by means of a tagged rope or cable which may be permanently stretched across the stream, or else placed at the time of gauging, this point depending upon local conditions. The zero point of this rope or cable should always be set to a fixed point upon the shore above high water mark. In this way the individual soundings of every series will be taken over fixed points in the bed of the stream, these fixed points having their elevations established with reference to bench-mark mentioned above. From the data thus obtained it will be possible to plot a profile of the bed of the stream and as much of each bank as is necessary to bring the end elevations of the profile beyond the reach of flood-water.

This profile can be laid out to scale upon section paper and will prove valuable for computing discharge areas during periods of flood. Under ordinary conditions of discharge, soundings and velocity measurements can be obtained directly in the usual manner. In time of flood this is often impossible, but the water-level can easily be obtained with reference to the bench-mark and laid off upon the profile above described. From this the discharge area can be very closely estimated, assuming of course that the flood has caused no change of any account in the bed of the stream. At times when it is impossible to use the current-meter, surface velocities may be estimated by timing the passage of cakes of ice or floating debris over various portions of the discharge area. By using these in conjunction with the discharge area derived from the plotted cross-section, and applying the necessary velocity constants, a reasonable estimate of the flood discharge can be obtained.

The level-gauge should always be read upon the occasion of each gauging, and daily readings should be taken if possible. By plotting the gauge heights as abscissae and the corresponding discharges as ordinates, a discharge or "rating curve" is obtained, which is very useful in estimating discharge during extreme high water and for interpolating discharges to correspond to certain gauge-heights where opportunity for direct measurement has been lacking.

In connection with estimating annual run-off from discharge measurements, it should be noted that a value obtained in this way can only be termed an average one at best, and can be assumed as a minimum only if the annual precipitation for that particular year appears to be a minimum. An idea can be formed as to this by consulting the government records, if any exist, for the district in which the operations were carried on.

A reasonable indication of the run-off characteristics having been thus obtained, the question of artificial storage may be taken up as above described, provided the market demand makes such a course necessary.

Where more than one development location is available for any specific scheme, the question of choice of site opens up a wide field for discussion. From a hydraulic standpoint, the comparison would be based mainly upon available discharge and natural head, but if the scheme involves the generation and transmission of electric power, the location of the point of local distribution with reference to the sites of development introduces a new and important factor into the discussion, and it becomes largely a question of off-setting natural advantages against transmission distance.

Assume two sites upon the same stream having, as is often the case, approximately the same amount of water available, one site being adjacent to the point of electrical distribution and the other some distance away but having a considerably greater natural head.

As a general rule, the capital cost and annual charges for development will vary inversely with the head for the generation of a given amount of power; that is, the cost of a low head plant will be greater than that of a plant of the same capacity operating under a higher head, owing to the greater amount of water to be handled and the greater expense of low speed machinery. In the case under consideration, however, it is evident that the saving due to the development of the higher head must be offset against the capital investment and annual charges for transmission and transformation.

Here again the question of market requirement presents itself. Assume that the low head installation has sufficient capacity to meet the immediate demands of the market, and that, all things being considered, the comparative estimates place the balance to the credit of this plant as regards capital cost and fixed charges. Again, suppose twice this head is available at the other location. It is then evident that in the event of development, this plant, after meeting the market requirements, would have a reserve capacity equal to its already developed output, and the possible revenue to be derived from future market extension will be a measure of the value of this reserve power.

In the final analysis, therefore, the problem would resolve itself to this: Will the prospects of future market extension be such as to justify the additional capital expenditure and fixed charges, and the additional risk of service interruption, due to transmission and transformation?

It is to be understood that this is only one of an infinite number of cases that may be presented for solution, but the above will have served its purpose if it indicates in a general way the manner in which a hydraulic problem may be approached, and also the way in which the location, design and lay-out of a power plant may be influenced by the character and extent of the market.

In conclusion it may be said that on the part of the engineer, conservative judgment tempered with experience is very necessary, as the science of hydraulics, in so far at least as it deals with the phenomena of flow in natural channels, is based upon very approximate assumptions and is governed by obscure natural laws. For this reason an engineer may manipulate coefficients and constants in such a way as to involve very elaborate and impressive calculation, while an error in some fundamental assumption may discount his results to the point of absurdity. In the finer points of design, accuracy is of course essential, but in the preliminary studies it is a hundred times more important to be safe.

COPPER ANODES IN CHLORIDE SOLUTIONS

SAUL DUSHMAN

In the following paper I intend to give a summary of an investigation undertaken with the object of explaining the anomalous behavior of copper as anode in chloride solutions. Preliminary experiments showed that copper dissolved with a valency ranging from 1 to 2, according to the experimental conditions. It was observed that in concentrated hydrochloric acid solution, it dissolved as a univalent metal, while in more dilute solution the valency was greater, and finally attained a value of 2 for very dilute solutions. The particular concentration of hydrochloric acid at which the copper ceased to dissolve as purely univalent (i.e., cuprous) varied with the rate of stirring, rate of circulation, current density, and other factors. Increased stirring or circulation caused the metal to dissolve much more as cuprous, while increasing the current density, under otherwise constant conditions, increased the proportion of cupric.

Although several hypotheses could have been made to explain these experiments, the one chosen seems to be in best accord with the quantitative experiments described below. *It is assumed that the copper anode dissolves by the action of the curreut in such a manner that, at the boundary between solution and electrode, the chemical equilibrium between the cupric and cuprous salts in hydrochloric acid solution is maintained.*

The investigation therefore naturally divided itself into two parts: (a) Investigation of the chemical equilibrium, (b) determination of concentrations at the electrode in the electrolytic experiments. The chemical equilibrium between cuprous and cupric salts has been investigated by E. Abel,* R. Luther,** and Bodlander and Storbeck.*** A large number of experiments performed by myself, in which the methods of analysis and manipulation were different from any of the above, proved in conformity with those of the last named authors. The equilibrium between copper, cupric and cuprous salts in presence of hydrochloric acid is represented by two equations:

$$Cu + CuCl_2 \rightleftarrows 2\ CuCl \ \ldots\ldots\ldots\ldots\ (1)$$
$$CuCl + HCl \rightleftarrows HCuCl_2 \ \ldots\ldots\ldots\ldots\ (2)$$

Cupric chloride dissolves metallic copper, according to (1), with the formation of a cuprous chloride. As well known, the latter is insoluble in water, but is soluble in hydrochloric acid solution, this fact being explained by the formation of the "complex salt" $HCuCl_2$, according to (2). Each of the above reactions is a reversible one; it ceases when there is attained in the solution a definite ratio between the products of the concen-

---

*E. Abel, Zeit. f. Anorg. Chem., 26, 361.
**R. Luther, Zeit. f. Physik. Chem. 36, 385.
***G. Bodlander and O. Storbeck, Zeit. f. Anorg. Chem., 31, 1, 458.

trations of the reacting substances on both sides of the equation. This last state is defined as an equilibrium. Assuming dissociation of the various salts taking part in the above reactions, the equations may be written thus:

$$\overset{0}{\mathrm{Cu}} + \overset{++}{\mathrm{Cu}} \rightleftarrows 2\,\overset{+}{\mathrm{Cu}} \;\ldots\ldots\ldots\ldots\; (1a)$$

$$\overset{+}{\mathrm{Cu}} + 2\,\overline{\mathrm{Cl}} \rightleftarrows \mathrm{Cu\overline{Cl}_2} \;\ldots\ldots\ldots\ldots\; (2a)$$

According to the "Mass Law," when equilibrium is attained between copper, cupric and cuprous salts in hydrochloric acid solution, we must have the following relations:

$$\frac{(\overset{++}{\mathrm{Cu}})}{(\overset{+}{\mathrm{Cu}})^2} = k_1 \;\ldots\ldots\ldots\ldots\; (1b)$$

$$\frac{(\mathrm{Cu\overline{Cl}_2})}{(\overset{+}{\mathrm{Cu}})\,(\overline{\mathrm{Cl}})^2} = k_2 \;\ldots\; (2b)$$

where the symbols in brackets denote the concentrations of the particular ions. Bodlander and Storbeck determined the values of the constants k_1 and k_2 to be 1.4×10^4 and 4×10^4 respectively, concentrations being taken in mols (formula-weights) per litre.

The second part of the investigation had for its object the determination of the concentration at the anode during the electrolytic experiments, so that the values of k_1 and k_2 might be calculated from these and compared with those obtained from the equilibrium experiment. Fig. 1 is a diagram of the electrolytic cell used. It consisted of two porous cylinders, P_1 and P_2, between the ebonite discs, *E E*, two concentric glass cylinders, *L* and *M*, also held between ebonite discs, and a rotating copper anode, *A*, making contact with a shaft and holder, *H*. To prevent liquid from entering within the anode tube, two ebonite plugs (the lower of these having a glass tip, *T*) were provided with threaded holes, so that they could be tightened against the copper, as shown in the diagram. The tube could therefore be taken off the plugs and weighed. Its area was about 40 square centimetres. A rubber tube, with stopper, *S*, fitted over the upper plug. The electrolyte entering *B* passed between the two porous cylinders, through holes in the center disc, *E*, and the glass cylinder, *M*, and up and around the anode, leaving by means of the exit tube, *D*. The cathode consisted of a platinum gauze, *C*, attached around the discs *E*. The different parts were cemented together. Cork wedges between the discs and the glass container, *F*, prevented any lateral motion of the discs when the anode was set rotating.

Since hydrochloric acid containing air in solution dissolves copper even without current, the solution to be electrolyzed was always freed from air by exhaustion, and then saturated with carbon dioxide. Blank experiments showed that in such a solution the copper dissolved only very slightly. A large bottle filled with stock solution was permanently connected with a carbon dioxide generator, and as the solution ran out into the cell, the gas took its place. After circulating through a cell once, the electrolyte passed into a measuring cylinder, and was then discarded. A copper coulometer and ammeter were placed in series with the cell. During the experiment, the rates of circulation and stirring were kept nearly constant, the average speed of rotation being about 1,500 per minute in all the experiments.

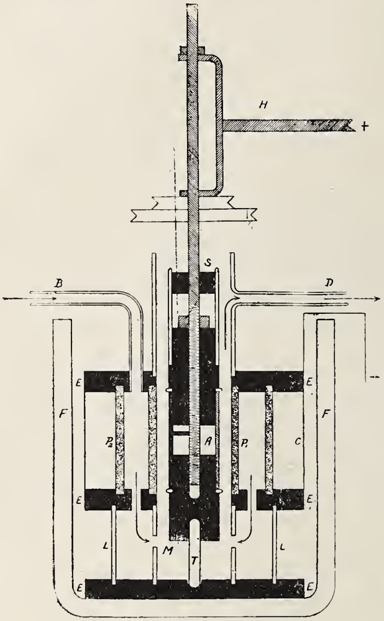


Fig. 1

The anode tube was weighed before and after electrolysis and the loss compared with the gain at the cathode of the coulometer. By means of the measuring cylinder the total volume of solution, V ccm, passed through the cell during the electrolysis, was also determined.

It has been mentioned above that copper dissolved in these solutions with a valency ranging from 1 to 2; that is the ratio of anode loss to coulometer gain varied from 2 to 1. Denoting this ratio by $1 + a$, it is evident that for every 96540 coulombs, $(1—a)/2$ formula-weights cupric salt ($CuCl_2$) and a formula-weights cuprous salt ($CuCl$) would enter the solution. Hence the average concentrations in the solution, during the electrolysis, would be $(1—a)/2V$ and a/V, in formula-weights (or *mols*) per ccm. That, however, these would not be the same as the concentrations just at the electrode surface, is evident from the following:

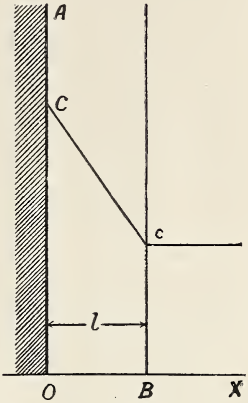


Fig. 2

In Fig. 2, let *OA* represent a section of the electrode, whose area is *S*. Let *OX* represent the distance from the electrode. It has been shown by Nernst and Brunner that in a rapidly stirred solution the diffusion is limited to a very thin layer close to the electrode, the thickness *L* decreasing with increasing rate of rotation. Outside this layer, the solution is of uniform composition. The concentration of $\overset{++}{\mathrm{Cu}}$, for example, at the electrode and in the solution are represented by *O C* and *B c*, respectively. Owing to the circulation of the electrolyte, the concentration in the solution rapidly attains the constant value *B c*, and the distribution of concentrations in the layer is given by the line *C c*. Now since all the concentrations remain constant during the electrolysis, it is evident that the following relation exists between *O C* and *B c*:

The amount of cupric ion entering the layer in any time is equal to the amount diffusing out into the solution, together with the amount transported in the same time, or

$$\frac{(1-a)\,i\,t}{2 \times 96540} = \frac{D_1\,S\,t\,(C-c)}{L} + \frac{(1-a)\,n\,i\,t}{2 \times 96540}$$

where $i =$ current in amperes,
$t =$ time in seconds,
$D_1 =$ diffusion constant in cms/sec.,
$n =$ transport number of ion in the solution.

Since $c = (1-a)it/(2 \times 96540\,V)$ where $V =$ volume in cc., as shown above,

$$C = \frac{(1-a)\,i\,t}{2 \times 96540}\left(\frac{1}{V} + \frac{L\,(1-n)}{D_1\,S\,t}\right)$$

It will also be observed that the concentration of $\overset{++}{\mathrm{Cu}}$ in the solution was assumed to be the same as that of $\mathrm{CuCl_2}$. The cuprous salt was, however, present in the solution as $\overset{+}{\mathrm{Cu}}$ and $\overline{\mathrm{CuCl_2}}$, the ratio between these being determined by the value of the concentration of $\overline{\mathrm{Cl}}$, according to equation (2b) above. Denoting by *b*, the fraction of cuprous salt present at $\mathrm{CuCl_2}$, and remembering that the average concentration of cuprous salt in the solution would be ait/96540 *V*, it is evident that

$$C^1 = \frac{abit}{96540}\left(\frac{1}{V} + \frac{L\,(1-m)}{D_2\ S\ t}\right) \ldots\ldots\ \ldots\ldots (4)$$

where C^1 = concentration of $\overset{-}{\text{CuCl}_2}$ at anode surface

D_2 = diffusion constant of $\overset{-}{\text{CuCl}_2}$ in cms/sec.
m = transport number of ion in the solution,

while the other letters denote the same quantities as in (3).

Since the equilibrium (2a) must hold at the anode surface as at every other point in the solution, it follows from (2b) that

$$\left(\overset{+}{\text{Cu}}\right) \text{ at the anode, } = \frac{C^1}{k_2(\text{Cl})^2} \ldots\ldots\ldots\ldots (5)$$

Having obtained in this manner the concentration of $\overset{+}{\text{Cu}}$ at the anode, it remained to calculate the value of k_1 according to (1b), by making use of equations (3) and (5).

The values of D_1, D_2 were calculated from the mobilities according to the formulae of Nernst, Abegg and Bose; while the value of L was determined experimentally by a separate set of measurements. The thickness of the layer in which diffusion took place was found to be about 25×10^{-4} cms, with the rate of rotation used in this investigation. The fall in concentration in this layer was found to be very great. Thus, in one experiment with N/200 HCI, the concentration of $\overset{++}{\text{Cu}}$ at the anode was 0.8×10^{-3} while in the solution it was 0.5×10^{-3}.

The concentrations of HCl and CuCl_2, rate of circulation and current, were varied in different experiments, and after calculating the concentrations of $\overset{++}{\text{Cu}}$ and $\overset{+}{\text{Cu}}$ at the anode surface, the values of k_1 were determined according to (1b).

With constant rate of circulation, the value of k_1 was found to be constant, and independent of concentrations of HCl and CuCl_2, as well as of the current. But with increased rate of circulation the value of k_1 increased also, varying from about 0.5×10^4 for low rates to 2×10^4 for extremely rapid circulation. It was only after a great many experiments had been performed, and apparently useless results had been reconsidered from this basis of rate of circulation during the electrolysis, that this conclusion became evident.

But why should k_1 vary with rate of circulation? Our initial assumption does not allow for any such variation; k_1 should be a constant under all conditions. The only practical explanation seems to be increased oxidation of cuprous salt in the solution as the rate of circulation decreased. For suppose that in those experiments where the circulation was very slow, the cuprous salt in the solution became oxidized; then the calculated value of $(\overset{+}{\text{Cu}})$ would be too high, while that of $(\overset{++}{\text{Cu}})$ would be too low, and hence k_1 also too low. On the other hand, with very rapid rate of circulation, there would not be any time for the $\overset{+}{\mathrm{Cu}}$ to be oxidized while in the cell, and hence the calculated would approach more and more nearly the actual values as the rate of circulation increased; that is, k_1 would become more and more nearly equal to the correct value.

It will probably be possible to test this assumption by electromotive force determinations of the ratio of the concentrations of $(\overset{++}{\mathrm{Cu}})$ and $(\overset{+}{\mathrm{Cu}})$ in the circulated electrolyte. All I can state is that qualitatively the experiments fit in with the above oxidation theory; whether there is also quantitative agreement remains to be determined by the further work in which I am at present engaged.

THE DESIGN OF CANAL DIVERSION WEIRS ON A SAND FOUNDATION.

W. G. BLIGH, M. Inst C.E.*

Sand is proverbially an unsuitable material on which to found a solid structure of any kind, but, when this structure in addition acts as a dam in holding up water, nine persons out of ten would consider that its stability under such circumstances was absolutely impossible.

Such, however, is by no means the case, and the object of this paper is to show the means adopted to insure the safety of structures such as river weirs, which are not only exposed to undermining by their foundation being washed out by subsoil percolation, but are also subject to the erosive action of the powerful current of a river in flood, which completely submerges the whole work. Not having its base resting on solid impervious material as clay or rock, the masonry of which the weir is composed is further subjected to the disability of loss of weight by displacement, which often amounts to one half of its weight in air.

When a dam of earth, as a reservoir embankment, is thrown across the sandy bed of a stream, leakage will necessarily take place beneath the base of the dam. With a low level of water in the reservoir this leakage may be quite harmless, that is to say, the percolating water will not carry with it any particles of sand; when, however, the depth of the water in the reservoir, that is, the head acting on the base, is increased, the percolating undercurrent will likewise increase in volume and velocity and will eventually convey particles of sand along with it and so gradually undermine the dam.

The weight of the dam is naturally the same whatever be the depth of water impounded, and further, sand is practically incompressible, consequently the imposed load must be ruled out

---

Extracts from an address delivered before the Engineering Society, Oct. 14th, 1908.

as a determining factor in this case. The real factor influencing the safety of the work is the length of the enforced percolation, or as it is technically termed the creep of the undercurrent, which is clearly identical with the base width of the earthen dam. This length of percolation must naturally be some multiple of the head of water acting on the work, and if we can only find out a safe value for this multiplying co-efficient, suitable to the particular sand under consideration, we shall be enabled to design any structure on a sand foundation with perfect confidence as regards its safety with reference to statical considerations.

An example of the successful construction of a dam on a sand foundation is that of the Amani Shah storage reservoir at Jeypore in India. This dam upholds a depth of over 30 ft. of water. It is built of sand and is founded on pure sand, but its base width is exceptionally great, being over 350 ft., i.e., 12 times the head. The silting up of the river bed, which occurred before the full flood level was reached, increased the effective value of the length of creep by over 100 feet, and thus enabled the work to stand an increased head of 44 feet in perfect safely. This dam is not water tight, and does not pretend to be so, but the visible leakage is unimportant.

The natural question will arise, if this is the case, why are the foundations of bridges over rivers, reservoirs, dams, etc., always carried down to solid rock or clay? The answer is that in these cases it is cheaper to do so. As we shall see later, the correct value of the requisite base width will be from 10 to 20 times the head, consequently in case of a dam 60 ft. high founded on sand, a base width of say $15 \times 60 = 900$ feet would be necessary for safety. Thus it would, as a rule, be more economical to adopt a deep foundation. As regards a river bridge, isolated piers of great depth are generally the only practicable and economical method of construction.

In large rivers the bed of sand is often of great depth, the piers of the Benares Railway Bridge over the Ganges River had to be sunk over a hundred and fifty feet through the sand before clay was met with; consequently, for a continuous work, like a river weir, a deep foundation is an economic impossibility.

The definition of the term weir, in contradistinction to that of dam, implies that the river water falls over its crest, whereas in the case of a dam the surplus flood water is conveyed either through the body of the work, as in the case of the Assuan Dam in Egypt, or else its escape is provided for by a specially built waste weir distinct from the dam itself. Weirs built across rivers, with sand beds of great depth, are invariably what are termed "diversion" weirs, that is to say, their function does not include that of the storage of water, but is limited to the diversion of a portion of the discharge of the river down a canal through an intake; a good example of this is the Calgary canal head in Alberta.

The function of a weir is to raise the water of the river when the latter is at a low level, in order to pass a sufficient supply down the canal. During flood time, or whenever the supply exceeds the demand, the crest is topped and the surplus water follows its course down the river. Owing to the sandy nature of the bed, which in part is carried along in suspension during floods, deposit takes place in rear of the weir almost to crest level, and in some cases even higher, so that during low water there is but a narrow channel from which supply can be drawn. This channel is artificially conserved by the adoption of weir scouring sluices in close proximity to the canal intake. As canals, when on sand, mostly take off at not more than 2 to 5 feet above river bed level, and their full supply depth seldom, if ever, exceeds 10 feet, it is clear that the height of these submerged diversion weirs will not be greater than 15 feet, the general average being 10 or 12 feet. On boulder or clay formations much greater heights are practicable.

A dam is subjected solely to hydrostatic pressure, but a weir on the other hand has also to withstand the dynamic scouring action of water. The design, however, is mainly influenced by hydrostatic considerations, for which alone precise rules can be framed, with, however, this proviso that the design of the work must also suit what may be termed the hydrodynamical side of the question.

The following facts may here be noted:—

The hydrostatic pressure on a weir is greatest when the head water stands exactly at crest level, the river bed being empty below; when this occurs the hydrodynamical forces are nil.

Again, when the latter forces are a maximum, *i.e.*, during full flood, the hydrostatical pressure on the weir foundation is at a minimum.

The hydrostatic problem, with water at rest, will first be considered as follows:—

Figure 1 represents a pipe line BC, proceeding from the bottom of a reservoir of water. The original head *H* is the difference of levels between A, the summit level, and C, the tail water, it being presumed that the outlet at C is free and unrestricted. The line A_1 C drawn from a point near the summit level to C, is termed the hydraulic gradient, or grade line, and the hydrostatic pressures on the pipe at any point are

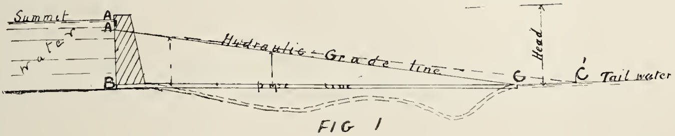


FIG 1

measured by vertical ordinates drawn up to this line. The distance AA′ is the head due to the uniform velocity of the current in the pipe plus a further small quantity representing loss of head at entry.

Fig. 2 represents a simple section for a low masonry weir, built on river sand, supposed, as is usually the case, to be completely submerged during floods. Such a work must necessarily consist of a vertical wall of masonry, or any other material, whose function is to uphold the water, connected with which, is a horizontal apron of some description, for protection against erosion of the river bed by falling water. In this particular case an impervious masonry floor is provided. The base of this floor C D, rests on a stratum of pure sand. The vertical wall holds water up to the summit level H, the tail level, *i.e.*, the original low water level of the river, is supposed to be at B, *i.e.*, coincident with the floor surface. The head *H* is the difference of level between the summit and tail levels, which is a maximum when the reservoir level is flush with the weir crest. The reason for this is that when the water overtops the crest the velocity of the film passing over exceeds that of the tail water in the normal channel below, consequently the rise of the tail water will be more rapid than that of the head water—the ratio being from 2 or 3 to 1, varying mainly with the slope of the river bed. The action of the impounded water in its endeavor to reach its own level, a property inherent in liquids, is to force a passage through the sand stratum underneath the impervious floor, the particles of liquid taking a curved course, first downwards then horizontally, and once the obstructing plane is passed, upwards.

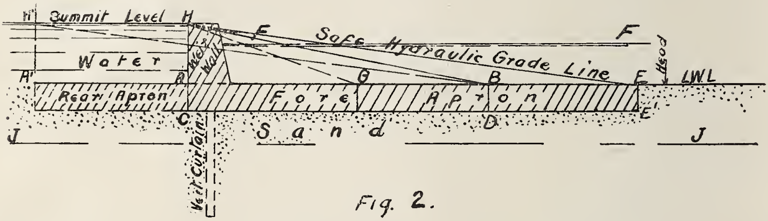


Fig. 2.

The proposition here presented is exactly similar to that in Fig. 1, the only difference being that instead of the water being confined in a pipe of a limited size, it is confined within the sand substratum, being prevented from rising above it. The theoretical velocity due to the head of water, is reduced in the pipe by friction against its sides to a smaller constant velocity right through; in exactly the same way, reduction, or neutralization of head is effected by friction in the passage of water between the particles of the sand. The greater the length of the confined passage, the less will be the velocity of the slowly percolating stream.

It is evident that under similar conditions of head and base length, the velocity of the current in different weir beds must vary with the nature of the sand stratum in accordance with its qualities of fineness or coarseness. Fine sand will be closer in texture, passing less water at a given head than a coarser variety, at the same time fine sand will be disintegrated and washed out under a less pressure. The problem now to be solved is evidently what proportion the base CD, or *l*, should hold to the head *H* in order to insure safety from washing out or from what is technically termed "piping." This value can only be obtained experimentally, that is, by deduction from sections of existing successful river weirs. Fortunately there are also some most instructive examples of failures due to insufficient length of base, so that the safe value of the relation of *l* to *H* can be deduced with absolute certainty.

In Fig. 2, supposing the length of the base CD or *l*, of the floor (which clearly must be some multiple of *H*) provides a length of creep or percolation sufficient to reduce the head, or, strictly speaking, the velocity of the current, to such proportions, as will just prevent piping. Then the hypothenuse HB will represent the hydraulic gradient. This slope starts from the summit level itself, for this reason, that the velocity head is insignificant and the loss at entry is nil. This gradient is found to be about 1 in 10 for fine sands and 1 in 8 for coarse sands, and might be termed the equilibrium gradient. Now the water having free egress at the point D, the conditions are identical with those in Fig. 1, and the upward head of water, acting on the base of the floor CD will be correctly represented by the vertical ordinates of the figure HCDB, and the total pressure by the area HCDB.

In this discussion the symbol *W*, commonly employed to represent the unit weight of water, *i.e.* the weight of one cubic foot, approximately 62.5 pounds, is invariably omitted. Where weight comes under consideration it is represented by Volume Specific Gravity, or by $V\rho$, the Greek letter ρ being used to indicate Specific Gravity, being preferred to the letter *G* sometimes employed for the same purpose, since the latter may possibly be confounded with the recognized symbol denoting Gravity. In the same way, the pressure of water is represented by *H*, the head, it being actually of course *HW*.

With regard to the value to be assigned to *l*, in actual construction a considerable factor of safety is necessary, so that the safe value of *l* must be half as much again as its bare value. If the floor be thus increased in length to the point E, so that CE=1½ CD, the safe hydraulic gradient will be HE, and the value of *c* in the expression $l=cH$ will become 15. This lengthening of the floor will, however, have the effect of increasing the upward pressure on it in proportion as the ordinates of HCE'E are greater than the ordinates of HCDB, consequently there is a positive disadvantage in lengthening the impervious floor beyond what is necessary to insure an absolutely safe base length, *i.e.*, one sufficient to prevent disintegration of the sand substratum by piping.

Supposing the length of floor reduced below the minimum CD, to CG, the hydraulic gradient then will be HG. The ordinates of the pressure figure are less than in either of the preceding cases, but failure will take place by piping, the floor becoming gradually undermined, by the sand being slowly washed out, the reduction of the velocity effected by friction in this shorter length being insufficient to overcome the disintegrating horizontal influences of the current of water. Two such cases have actually occurred in the case of the Chenab and the Jhelum weirs.

It is self-evident that the effective weight of the floor must equal or exceed that of the upward hydrostatic pressure unless its construction is such as to render it capable of resistance to bending stress. In the case of Narora weir a floor of insufficient weight has been known to stand for several years, but eventually, owing to a comparatively small increase in the upward pressure, it blew up. Weight in the floor and superstructure generally, well in excess of the hydrostatic pressure, is always a desideratum, and is only limited by considerations of economy.

We have already seen that the proportion of $l : H$ or the value of c, the expression $l = cH$ varies in different rivers. River sands will be classified according to the following known qualities.

Class 1a—The Nile River sands. Coefficient adopted 18.

Class 1—Fine light micaceous sands such as are found in rivers taking their source in the Himalayas, including the Ganges, Jumna, Indus, and the four main Punjab rivers; to this class belong also the sands of the Colorado River. Coefficient adopted 15.

Class 2—The coarse-grained sands of the rivers of Central India, Madras and Bengal; most river sands belong to this class. Coefficient adopted 12.

Class 3—Boulder and sand formation. Coefficient adopted 6 to 9.

The coefficients are all obtained from actual examples.

With regard to hydrostatic pressure on the base the following points require notice.

In Fig. 2, if a hole were bored in the floor CE′ and a pipe inserted, the water would rise up as far as the existing hydraulic gradient HE. The head acting on the base CE′ at that point would thus be represented by the ordinate of the figure HCE′E, and not of the triangle HAE. That is, to what may be termed the external head is added that due to displacement. To avoid confusion, the extraneous head of water symbolized by H, which always means the difference of levels above and below a weir or regulator, will be kept distinct from that due to displacement or immersion, this latter pressure being allowed for by reduction in the effective weight of the immersed body. As is well known a solid material immersed in water loses effective or sensible weight corresponding to the weight of water displaced. Thus a body whose specific gravity is ρ has a weight in air of $V\rho \times 62.5$ pounds, if V be its volume in cubic feet, but when immersed in water its effective weight is $V(\rho-1) \times 62.5$ pounds.

In the figure when the low water level is at E the floor ACEE′ is clearly just immersed, and the upward pressure due to displacement will be equivalent to the weight of water displaced. When the tail water is at some higher level, as at FF, the status as regards upward pressure due to displacement is in no way altered, the increase of upward pressure below the slab, due to the greater depth of immersion, being compensated for by a similar increase in the downward pressure upon the top of the slab.

When the tail water is at the level CDE′, the weight of the floor is clearly unimpaired by flotation, when intermediate, the effective weight of that portion of the floor lying below the level has alone to be considered as thus impaired.

When the floor is built well above LWL, as when the LWL is at JJ, the sand substratum being porous, the water level will rise up to the base of the impervious floor thus practically reducing the head from HJ to HC. The acting head therefore cannot be taken as extending below the actual impervious base of the weir, except as regards calculation for base length, or length of creep.

In Fig. 2 it is evident that the value of l is in no way affected, whatever be the position of the vertical drop wall with regard to the horizontal floor. For instance suppose the floor extended backwards to A′ and AA′ made = BE, then the action of the head of water is thrown back from H to H′ the hydraulic gradient will be H′B parallel to HE, and the statical condition is in no way altered.

This rear projection is termed the rear apron. Its value in design has only recently been recognized. The upward pressure acting beneath the rear apron will be simply that due to displacement, and as the value of ρ for the materials employed in the construction of the apron is greater than unity, this upward pressure due to flotation is more than counterbalanced by the downward pressure due to the weight of the floor. As the rear apron is in addition free from the erosive action of falling water, it can be constructed of less expensive material than the fore apron or floor. On the other hand it must be impervious and must have a water-tight connection with the weir wall, otherwise the head may act between it and the weir wall, thus practically isolating it from the rest of the work. This actually occurred in the case of Narora weir. Another weir, the Chenab, failed by sinkage of the floor, the sand base having been gradually washed out by the undercurrent.

Theoretically, the rear apron would be effective if only a thin impervious layer, but practically it is considered that unless constructed of a definite weight, water passing underneath it would partake of the nature of a surface current and so the apron would not be effective in the neutralization of head.

With weirs of ordinary height, with a sand coefficient of 12 to 15, and with a value of H up to 15 feet the economical length of the rear apron will not exceed 3 to 5 H. The reason being that the rear apron performs but one function, namely, statical, whereas the fore apron in addition to this, acts as an anti-erosive shield; consequently material placed in front of the drop wall is of greater value than that in rear, and if the rear apron is designed too long there will necessarily be excess material in the whole section, which by a more economical distribution could be avoided. The reason for this is that dynamical considerations cannot be lost sight of and the requirements to meet this second governing condition demand a certain minimum length of fore apron symbolised by L which is measured from the toe of the drop wall. This length consists in part of the masonry floor designed to meet the requisite length of creep, i.e., for statical requirements, and when this length falls short of the minimum the balance has to be made up by loose stone rip rap as a further protective covering to the sand. This latter portion is termed the talus.

The value of L is influenced by the erosive power of the current, which again is dependent on the proportional obstruction afforded by the weir, i.e., the height of the masonry crest combined with the shape of its profile, and the velocity of approach at flood times. These several considerations will determine the designer as to what value will be suitable for adoption, having due regard to precedent.

For direct overfalls with floor at LWL the value of L may be taken as from 15 to 20 H for class 1, and 12 to 16 H for weirs of class 2, H in this case not being necessarily the maximum statical head but the height of the permanent masonry weir crest above floor level.

The summit level in all modern weirs is raised by means of collapsible crest shutters, which fall automatically in flood times, to a height varying from 2 to 6 feet above the solid masonry weir crest. This device lessens the permanent obstruction to the normal river waterway.

We have hitherto been considering only a section which has no vertical depressions in the base line. The creep of water beneath an impervious apron is known to hug all vertical sinuosities. Thus if a row of sheet piling or some other impervious curtain were inserted below the base CE in Fig. 2, the line of creep would be forced down one side of the vertical obstruction and up the other. This added length of creep is thus twice the depth of the curtain. The insertion of sheet piling or other form of curtain-walling is thus a most valuable means of increasing the length of creep and thus saving length in the expensive horizontal apron.

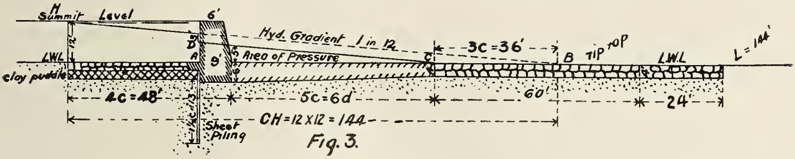


Fig. 3.

An example of the method of applying the principles already enunciated will now be given for the design of a weir under assumed conditions, viz. :—

$H = 12$ feet.

River, Class 2 with $c = 12$. Whence $l = c \times H = 12 \times 12 = 144$ feet.

The first point to be decided is the length to be given to the rear apron, and the depth of the sheet piling, as it is proposed to adopt a curtain below the weir wall. The thickness of the fore apron at the toe of the drop wall, which is the crucial point in the whole design, is determined by the values thus adopted, for this reason, that the unbalanced hydrostatic upward pressure is here first felt and the neutralization of head up to this point should be sufficient to reduce the required depth of floor to reasonable and economical dimensions. The minimum average thickness of the fore apron is obtained by the empirical formula $T = \sqrt{\frac{3h}{2}} + 1\frac{1}{2}$ where h = height of solid masonry weir in feet and T = thickness of fore apron in feet. In this case $T = \sqrt{18} + 1\frac{1}{2} = 5\frac{1}{2}$ feet nearly.

In designing these weirs it is a great convenience to make all dimensions multiples of the coefficient c, as then each unit represents a neutralization of one foot of the original head. The length of the rear apron should be measured back from the toe of the drop wall. In the design this length is made $= 4c = 48$ feet. Deducting the base thickness of the weir wall, which is 9 feet, the actual length of the rear apron is about $3c$ feet. This, if anything, is somewhat short, a length of $3\frac{1}{2}c$ feet would give better results. The thickness of the rear apron, composed of puddle covered with stone rip rap, will be 5 feet, it cannot be less.

Now we come to the sheet piling, steel or concrete steel. This is made $1\frac{1}{2}c$ or 18 feet in depth, consequently the total neutralization of head effected up to the toe of the weir wall is $(4 + 3)$ ft. = 7 feet, leaving 5 feet hydrostatic pressure head acting here. The value of ρ for the material in the masonry fore apron will be taken as 2 (a common low value). The apron is submerged, lying below L.W.L., its effective weight will therefore correspond to $(\rho—1)$. Now, as the effective weight of the floor should (it is deemed) exceed the upward pressure by at least one-fifth, as a precautionary measure, with a hydrostatic pressure due to 5 feet of head the necessary thickness of masonry with an effective weight corresponding to $(\rho—1)$ will be $5 + 1$ or 6 feet. The length of the fore apron will be the remaining balance of cH, or $(12—7)c = 5c$ or 60 ft., and the terminal thickness, theoretically nil, is made 4 ft. for other than statical reasons. This ends the design as regards statical requirements. For anti-erosive purposes the floor will have to be continued as a talus of loose stone pitching for another 84 feet, giving a length, measured from toe of drop wall, of $12H = 144$ feet. This, as we have seen, is obtained from an empirical rule, and can be varied as experience may dictate. The minimum length of fore apron is 4 to $5H$.

The graphical method of design is shown on the same figure and is very simple. From the extremity of the rear apron the total requisite base length, $= cH = 12 \times 12 = 144$ feet is set out to the point B. The line HB then is the hydraulic gradient of 1 in 12. From B set back BC = vertical portion of the base length $= 3c$ or 36 feet, and from the point C draw a line CD parallel to HB up to D, its intersection with a continuation of the vertical curtain.

The triangle DAC is the triangle of pressure.

The thickness of the drop wall at its base is found by the following formula: $\frac{H'}{\sqrt{\rho}}$ in which H′ is the height above floor of the head water at the time when the tail water is level with the crest, being generally 1½ times the height of the solid drop wall. But when the maximum statical head, *i.e.*, to shutter crest exceeds this, H' will become H and the formula $\frac{H}{\sqrt{\rho}}$

We will now give another example of design of a direct overfall weir with floor at LWL, viz., that of an alternative design for the Chenab weir. The actual given conditions are:—

$H = 13$ $c = 15$. Whence l must $= 13 \times 15 = 195$ feet.

In this design the original arrangement is followed of having the permanent drop wall of low elevation, the requisite summit level being obtained by the use of steel collapsible crest shutters As in the existing work, the level of the crest of the drop wall is placed at seven feet above extreme low water, while the remaining 6 feet required to bring the summit level to RL 728 is provided by the shutters. (See Figure 4.)

The commencement of the rear apron is placed $4c = 60$ feet behind the toe of the weir wall, below which sheet piling $1c$ or 15 feet in depth is provided. These neutralize 6 feet of head leaving a balance of 13—6 = 7 feet, hence a farther base length of 7 × 15 = 105 has to be provided in the fore apron. This is too long for actual requirements, which are 5 *H* = 65 feet, consequently another row of sheet piling is introduced at the end of the floor with a depth of ½*c* = 7½ feet. This admits of the curtailment of the floor by *c* or by 15 feet, reducing it to 6*c* or 90 feet. There are thus two vertical depressions in the base line.

The graphical diagram is shown in figure 4A. First, the total required base length or 15*H* = 15 × 13 = 195 feet is measured off from the commencement of the rear apron, and the hypothenuse is drawn in from the point thus obtained. Secondly, the respective values of the two vertical depressions are set back, viz., 2*c* = 30 feet, and *c* = 15 feet. A line parallel to the hydraulic gradient is then drawn from the first-mentioned point up to its intersection with a vertical through the first row of piling. A second parallel cannot be drawn from the second point as the intersection with the vertical is at the same spot, consequently the second step occurs at this very point. The outline of the pressure area below the weir wall is not a triangle, as heretofore, but a trapezium. The value of *ρ* is here 2¼; the thickness of floor necessary to counterbalance by its weight the hydrostatic pressure will thus be about 6 feet. (See figure.) This thickness is hardly sufficient and should be increased to 7 feet at least.

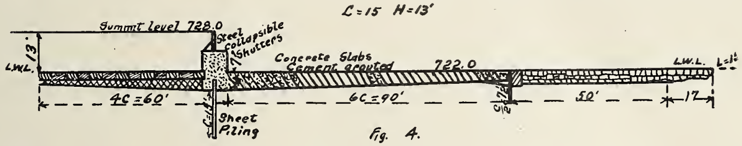


Fig. 4.

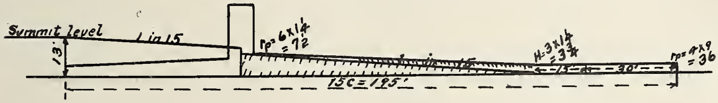


Fig. 4A

The rear apron is composed of puddle overlaid with concrete slabs, the weir wall is of concrete, the fore apron is of concrete slabs laid on a slope, breaking joint, subsequently cement grouted. This is a novel but economical method of subaqueous construction, and was first adopted at the Colombo breakwater.

This design would, (it is now considered), be improved by increasing the length of the rear apron from 4*c* to 5*c*, and correspondingly reducing the fore apron to 5*c* or 75 feet, the thickness could then remain as it is in the drawing. This example is useful as showing the ease with which the design can be altered by manipulation of the length of the rear apron and depth of rear curtain, till the most economical arrangement is arrived at.

THE NEW THERMODYNAMIC AND HYDRAULIC LABORATORIES OF THE UNIVERSITY OF TORONTO

ROBT. W. ANGUS, B. A.Sc.
Professor of Mechanical Engineering

During the past years the growth of the Faculty of Applied Science and Engineering has been very rapid indeed, and as is common in such cases, the increase in accommodation has not kept pace with the increase in the attendance. On this account the buildings have been overcrowded in every way and the consequent pressure has become very great.

This pressure has been felt very greatly in the Thermodynamic and Hydraulic laboratories, where, partly on account of the somewhat rapid development of steam and gas plants and the desire on the part of Canadians to develop their water-powers, and partly because of the growth of the Faculty, the attendance has increased rapidly from year to year. To meet the increased demands new apparatus has from time to time been installed until the available space has been used up, and the crowding has caused complications to arise between the two laboratories, making the work difficult. It has also been impossible to give any work in these laboratories to the Third Year students, so that they have been unable to follow up the lecture work with experiments which would illustrate the points brought out. To overcome these defects the new laboratories are being built.

The new building, known on the architect's plans as the Thermodynamics Building, contains a Thermodynamic laboratory, an Hydraulic laboratory, a boiler room, some private rooms for the staff and study and work rooms for the students.

The building faces the west and the front part of it, only a portion of which is now being erected, will contain in the basement students' rooms and a machine-shop, and on the upper floors the offices and study rooms connected with the work. This section of the building is the only part not now being completed.

On the south side of the building is the Thermodynamic laboratory, one storey high, covering a space 155 feet by 60 feet, the light all being obtained from the roof. This laboratory, which is high and airy, is divided into two parts, one of which is 40 feet wide and runs the full length of the building. In this part all the steam and gas engines will be installed as well as some other machines, and the whole area will be served by a travelling crane 40 feet long running from end to end of the building. This section is to contain a triple-expansion engine, simple and compound engines of various types, an air compressor, steam turbines, apparatus for testing injectors, indicators, etc., gas and oil engines of various types and other apparatus of similar nature. Most of this apparatus will be put in as soon as the building is completed. The other part of the laboratory, which is 20 feet by 155 feet, is partly taken up by the goods entrance but mainly by small laboratory rooms about 15 feet by 20 feet each. It is intended to equip these rooms with such apparatus as a refrigerating machine, air brake apparatus, a suction gas plant, valve setting engines, apparatus for testing the value of lubricants, etc., and they are so arranged that they will accommodate a small number of students who will be able to carry out experiments and be comparatively free from the noise and steam of the main part of the laboratory. These rooms have brick walls on three sides and open off the main steam laboratory by means of doors in a glass partition.

To the east of the Thermodynamic laboratory and at the back of the building is the boiler room, 45 feet by 70 feet, which is also lighted from the roof. This room will contain four boilers, three of which are now being installed and which are capable of running at a pressure of 200 pounds per square inch. One of the boilers is also arranged with a superheater. These boilers will be so piped up to the engines that complete engine and boiler tests may be made. The room also contains two chimneys specially arranged for the study of problems connected with chimney draft and capacity, and the necessary pumps and other apparatus. The boilers in this room are exclusively arranged for experimental work and are not used for regular service work.

The Hydraulic laboratory occupies the northern side of the building and this part contains three floors, the lower two of which are for the hydraulic laboratory and the upper one for study rooms. Each of the floors of the hydraulic laboratory is 40 feet by 112 feet, the distance between floors being 18 feet and 15 feet respectively, so that the rooms will be well ventilated and give good head room. This laboratory is lighted from the north and east sides by large windows running through the two storeys which occupy about three-fourths of the entire wall space.

The main or upper floor of the Hydraulic laboratory will contain a large weir tank capable of measuring six cubic feet per second, reaction turbines, impulse turbines and necessary tanks, orifice and weir tanks, various water meters, centrifugal pumps, apparatus for measuring the friction of water in pipes and hose, apparatus for the use of Pitot tubes, etc. A large pressure tank running through the two floors and up into the roof discharges into the large weir tank.

The lower floor is largely occupied by the measuring tanks and the pumps and engine for driving the latter. The pumps are high-lift turbine pumps specially arranged to give great flexibility for the purpose of laboratory work. In addition to the above there will be an open trough 5 feet wide, 4 feet deep and running the full length of the building, with a weir at the end, in which experiments on current meters and other apparatus may be made.

In designing the laboratories, care has been taken to provide for proper light and air, to arrange for the convenient handling of all apparatus, and to accommodate comparatively large classes of students. With this in view the arrangement will permit of the use of almost every piece of apparatus in the building at the same time and without interference of the experiments one with another. An endeavor has also been made so to arrange the apparatus that pieces especially adapted for research work may be continuously available in order that the work may be well carried out.

At a later date a more complete description with plans and drawings will be given.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published Monthly during the College year by the University of Toronto
Engineering Society.

BOARD OF EDITORS

K. A. MacKenzie, B.A.Sc. '06	Editor-in-Chief
W. J. Bolton, '09	Civil and Arch. Sec.
L. R. Wilson, '09	Mech and Elec. Sec.
A. Duff, '09	Mining and Chem. Sec.
R. J. Marshall, '08	Ex Officio U. T E. S.

Associate Editors

H. W. Price, B.A.Sc., '01	Mech and Elec.
P. Gillespie, B.A.Sc.,	Civil and Mining
M. C. Boswell, M.A., Ph.D., '00	Mining and Chem.
W. Treadgold, B.A., '05	Railway

Advertising Committee

S. S. Gear, '08
T. H. Crosby, '09
R. H. New, '10
L. E. Jones, '11

Subscription Rates

Per year, in advance	$1 00
Single copies	20

Advertising rates on application.

Address all communications :

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

Editorial

Dean Galbraith

"Occasionally a man comes into the fruition of his life work while there is yet time to make it complete in the stimulating joy of appreciative recognition." This applies with special force in the case of Dean Galbraith. Largely through his initiative and untiring energy, the present Faculty of Applied Science of the University has developed from a very humble beginning to almost a commanding position among the Faculties. It will ever remain a fitting monument to his honor and to his memory.

To few men has the privilege and power been given to so indelibly stamp his impress upon those with whom he came in contact. The only regret is that the increasing growth of the School renders it impossible for undergraduates to come in personal touch with the Dean, as was the case in less prosperous days.

It was with considerable pleasure that the graduate and undergraduate bodies united to present his portrait to the University to show their appreciation of him. It is the earnest wish of all that he may be long spared to continue the work he has so ably planned and carried on to its present successful issue.

Prof. G. R. Mickle

Prof. George R. Mickle, who has been with the School of Practical Science for fourteen years, first as Lecturer and later as Professor of Mining, resigned last summer to give his whole time to his work with the Government. Ever since the early days of Cobalt, Prof. Mickle has been a prominent figure in that district as an official of the Ontario Bureau of Mines, as the first Inspector of Claims, later as the Head Inspector of Claims and for the past year as Mine Assessor. He is a Canadian, born at Guelph, educated at Upper Canada College and the University of Toronto, where he took honours in Classics. On receiving his B.A. he took the general engineering course at the S. P. S., graduating in 1888, and then spent two years in post-graduate work at Freiberg. Returning to Canada, he practised his profession as a Mining Engineer for several years at Sudbury. He was appointed Lecturer in Mining at the S. P. S. in 1894, and Professor of Mining in the University of Toronto in 1905. His summers were spent in the field in mining and exploration work in British Columbia, on Hudson's Bay and in other parts of Canada and the States until 1904, since when he has been with the Bureau of Mines. As Inspector of Claims he had to bear the burden of the difficulties encountered in the enforcement of the inspection clause which was so rigidly carried out in the Cobalt area and which played so important a part in the locations of that district. As the area increased and a large number of inspectors were employed, Prof. Mickle was placed in general charge of their work. Eighteen months ago he was appointed Mine Assessor and after carrying on this work jointly with his University work for one year, this work claimed all his time and he resigned his position as Professor. He is the second professor to join the Bureau of Mines. Dr. Miller, the Provincial Geologist, was also won from the academic life, he having been Professor of Mining at Queen's for some ten years. Conditions have not permitted such an extensive growth in the Mining department of the University as for example in the Mechanical and Electrical departments, but Prof. Mickle has built a splendid foundation for metallurgy and for mining. The laboratories in these departments, though not so heavily equipped as others of older growth, will hold their own with any in the Dominion in the possibilities of their teaching functions. The foundation is laid down on safe and broad lines and competent judges have expressed their satisfaction at the unselfish, broad-minded way in which these were laid, the funds available being spent entirely on fundamental essentials that often lent no outward lustre to his department but which meant much for the future. His career in the S. P. S. was marked by sterling loyalty and this same spirit has characterized his work in the field. The Government Department of Mines has given him the most difficult positions in their work; positions that require the most careful judgment, where decisions must be rendered that must be unassailable not only in their knowledge of mining but in their absolute fairness and impartiality. Had Prof. Mickle not left the academic life the Government would have been hard put to it to have found a man to fill his place in the field, and if the School has lost a valued colleague and friend, the Government and the field have gained a man whom most men like and whom everybody respects and admires. He is still in Ontario and will often be consulted in the policy of the School.

H. E. T. Haultain

H. E. T. Haultain is a Canadian by education and adoption. He was born in Brighton, England, in 1869, but was taken from England when only three months old. He was educated at the Public School and Collegiate Institute at Peterborough, Ontario, and graduated in the regular course in Civil Engineering at the School of Practical Science in 1889. He was prizeman in his first year, secretary-treasurer of the Engineering Society in his second and president of the Engineering Society in his third, being the first student president, succeeding Prof. Galbraith, who had been president during the first years of the Society.

On graduating he went to England and joined a mining engineer in London practically under the English form of pupillage, and was sent by him in charge of small operations in the South of Ireland, and afterwards to the St. Mauritius tin mines in Bohemia. While here he designed and operated the first electric mining hoist on the Continent of Europe (end of 1890). He subsequently took post-graduate work, first in London and then at Freiberg, and in 1893 joined the late Maurice Bucke in British Columbia and has been engaged in mining work ever since, in British Columbia, South Africa and several of the Western States. He returned to Ontario in 1905 to take charge of the Canada Corundum Co.'s works at Craigmont. His specialty is the mechancial treatment of ores but from the academic point of view his important specialty is the variety of his experience. He has held all positions from that of laborer with pick and shovel to that of general manager. He has worked all over the world in ores of tin, copper, silver, gold, lead, zinc and corundum. He has always maintained a high professional tone and of late has taken an aggressive public attitude against the wild-catting in Northern Ontario. He is a member of the two English exclusive technical societies, being an Associate Member of the Institution of Civil Engineers and a Member of the Institution of Mining and Metallurgy. He is a Member of the Canadian Society of Civil Engineers and a Member of Council of the Canadian Mining Institute and holds the degree of C. E. of the University of Toronto. His appointment to the only chair of Mining Engineering in this University was confirmed on October 8th last under the title of Associate Professor.

When asked why he deserted the field for the academic life, he replies that he has not entirely deserted the field, that he hopes there is room for both academic and field work and quotes from Sir Alexander Kennedy's presidential address to the Institution of Civil Engineers:

"It has been, no doubt, a source of regret to many, as it is to myself, that as years go on and experience accumulates, one's work comes always more and more to deal with men and matters, with general schemes and methods, even with financial means and possibilities, and less with the directly mechanical problems which fascinated us when we were younger, and for the sake of which—probably—we took to engineering at all in the first instance."

"The resignation of Professor George R. Mickle from the Professorship of Mining in the Faculty of Applied Science of Toronto University, in order to more closely identify himself with the provincial administration of the mining industry, has made it possible for his successor to be Mr. H. E. T. Haultain, a thoroughly equipped, admirably-poised, versatile, British born, Canadian bred and cultured, engineer. To succeed Professor Mickle, who enjoys the respect and confidence of higher educational authorities and mining scientists, is in itself an honor. Had Mr. Haultain not been what he is the selection might have brought to him the onerous task of measuring attainments with his predecessor. It is such exchanges, in which the Ontario Ministry and Toronto University Faculty have been happily fortunate, which give substance to the expectation that the mining sciences of Canada are to be exalted beyond mercenaries."
—The Mining Journal (London).

The Demand for Research Work

It is felt throughout the undergraduate body in Applied Science that more adequate provision should be made for those who desire to follow up their regular course by an additional year on research work. Of course under the conditions now existing with present equipment, post-graduate work in many of the courses is impossible. But this is not true of the mining and chemical courses, and no doubt much good work might be done in many of the other departments.

What, then, deters the men who may be desirous of extending their knowledge of any particular branch, from putting in an extra session's work? Granting that work could be done in the laboratories if such were requested, why is there no desire on the part of the graduates to continue investigations they may have begun? No doubt such desire on the part of the graduates does exist, but certain factors must be changed before there will be visible expression of that desire. No incentive now exists for a man to take up post-graduate work except his own interest in the investigations, and while this should be of paramount importance, still there must be some other goal in sight than the mere feeling of having thrown some new light on an old subject.

It is not intended to criticize present conditions, for it is understood that what at present exists is a result of past policies, but these observations are now offered in the light of the fact that the four year course will soon be an accomplished fact and as an expression of a strong sentiment among the graduates that something must be done in the immediate future.

Under the new regime, a strong interfaculty spirit is being developed throughout the University which is tending towards a sympathy of action and a unity of aim and purpose, and is gradually eliminating any sectional prejudices which may have heretofore existed.

If this feeling is to be fostered, there must be just and equal treatment to all, and this treatment may have to be granted perhaps at the expense of traditional rights and privileges.

Aids to Research in Other Faculties

A comparison with what is done towards rewarding a man for additional or post-graduate work, in other faculties, with what is done at the School, will be instructive. In the Arts faculty, a man who has shown capacity for original work may be granted a fellowship with a salary of $500. At the same time while holding this fellowship he is allowed to take a prescribed course of work, including lectures, and write off an examination leading to the degree of Master of Arts. And if he shows exceptional ability he is permitted to hold the fellowship for two more years and proceed to the degree of Doctor of Philosophy, during all this time following a course of lectures laid down by the University.

Disabilities for Research Work in Applied Science

For many reasons this is impossible for a graduate of Applied Science to do. First, his whole time is required of him for the accomplishment of the academic work allotted to him, and again no lecture courses in the University which deal with his work, are arranged for. Even supposing he were allowed a portion of time for work other than that allotted to him, still he would have no reason for following up a subject of interest to him other than the pleasure he might derive from his work. It is true that the degree of Doctor of Philosophy is now nominally open to graduates in Applied Science, but it is also true that in the list of subjects and courses given, there is absolutely nothing which is either of interest to them or which has the slightest bearing on their work. A glance at the list given in the University Calendar will satisfy anyone on this point. It may be said that provision is made for at least the mining and chemical men in the Ph.D. work, but these departments include an exceedingly small portion of those in attendance and no provision whatever is attempted for the Civil, Mechanical or Electrical men. Even the work which the miners and chemists might take does not approach the end aimed at, in their case.

Lack of Scholarships

Another point of interest in connection with the work in the Faculty is the lack of scholarships. It is appreciated that new conditions have arisen since the closer union of S. P. S. with the University, but the graduates feel that these new conditions require in turn a rearrangement of the old traditions and this rearrangement will not come until it is shown that it is required.

Disabilities of Applied Science

In looking over the regulations respecting scholarships, one is struck by a statement made there, that all undergraduate scholars must sign a declaration of intention to proceed to a degree in Arts in the University, before a scholarship will be granted. Surely a man holding a mathematical scholarship should be allowed the option of a course in the Faculty of Applied Science, for it is here the mathematical men naturally gravitate.

1851 Science Scholarship

Again, the 1851 Exhibition Science Research Scholarship of an annual value of $750 is awarded each alternate year to a University graduate. Under the general regulations governing this scholarship, it is stated that *the scholarship is intended to enable graduates to continue the prosecution of science in its application to the industries of the country.* Naturally, then, this scholarship should be given to the Faculty of Applied Science. In the last ten years, this scholarship has been taken by students of the Engineering Faculty at McGill. But here we do not even find the scholarship listed in the Applied Science Faculty Calendar, but placed in the Arts Calendar. However, in the Senate regulations, it is shown to be open to Engineering students. But let us look at the last award. Last year the scholarship was won by a thesis entitled "On Variations in the Conductivity of Air Enclosed in Metallic Receivers," and "On an Improvement in the Determination of Visibility Curves"

—*physical researches in pure science.* At the same time were entered two theses from Engineering students and one of these was on "the Discovery of a New Process of treating Cobalt Ores." No doubt from a pure science standpoint the first rightly won the scholarship, but considering the intention for which the grant was made, as an incentive for research of an industrial nature, the second certainly merited consideration.

Conclusions

In the light of the above facts, what changes should be suggested? It is the opinion of many of the graduates that post-graduate work should be allowed men who are holding fellowships, and a new Master of Science degree established, to be granted after a year's post-graduate work and under the same conditions as the M.A. degree; that the Ph.D. degree be made applicable to Applied Science graduates; that the 1851 Science Scholarship be handed over to the Faculty of Applied Science, or at least the intention of the founders of the scholarship be more rigidly adhered to, in the consideration of the subjects for theses.

NOTICE—PRIZES OFFERED

To stimulate the interest of undergraduates, a prize of $10 in books is offered in each section for the best paper presented for publication in "Applied Science," such papers to be available for sectional meetings if required.

THE ENGINEERING SOCIETY—OCTOBER

As usual, the first week or two were marked by very heavy work in the supply department. This year sees prices down practically to cost and the gain to the student body has been very material. That this was realized was shown by the very heavy purchasing in the supply department.

The first general meeting of the Society was held October 7th in the large lecture hall of the new Physics Building. Dean Galbraith was warmly received by the men as he delivered an informal opening address. The paper of the evening was presented by W. G. Bligh, C.E., of the Indian Government Service, on "The Design of Canal Diversion Weirs on a Sand Foundation." Mr. Bligh's address proved to be of special value to those of the men who are specializing on hydraulic work, as well as of general interest to all. Several elections were necessitated by the non-return of three officers of the Engineering Society. These resulted in the election of Mr. A. R. Duff, vice-president of Chemists' and Miners' Section; Mr. F. H. Moody, '08, recording secretary; Mr. S. S. Gear, Fourth Year representative; and Mr. L. E. Jones, First Year representative.

Owing to the special convocation of October 21st to confer the degree of L.L.D. on Earl Roberts and Lord Milner, the regular sectional meetings of the Society were postponed until October 28th. The Civil and Mechanical Sections combined to listen to a most interesting address by Rev. Dr. Crummy, B.Sc., D.D., on "General Engineering Development in Japan." Dr. Crummy, having spent a number of years in Japan, was able to point out many features of engineering which were instructive and in numerous instances highly humorous.

Following Rev. Dr. Crummy's address, a paper prepared by Mr. S. S. Gear, '08, on the "Lackawanna Steel Works," proved of great interest to the men. Plans of the works prepared the men to quite an extent for the visit to the works on the annual excursion.

The sectional meeting of the Chemical Section was addressed by Dean Galbraith on "Steel Manufacture." This address was listened to with intense interest by a large body of the men in anticipation of the excursion.

On Saturday, October 31st, what was probably one of the best annual excursions held by the School ran to Buffalo, some two hundred and fifty men turning out. The excursion was accompanied by Dean Galbraith, Prof. Wright, Prof. Bain, and several other members of the Faculty, and their co-operation as leaders of parties contributed largely to the success of the day. The reception accorded in Buffalo could not have been more cordial. The City Council very kindly granted permission to inspect the fire tugs, harbor and other interesting points, and the City Engineer did all in his power to make the visit profitable. At the Lackawanna Steel Works, Mr. Sheddon, general manager, and Mr. Davis, Chief of Police, gave every opportunity to the men of inspecting the various processes and operations. The hearty thanks of the Society is due especially to Mr. Davis for his personal efforts in supervising the arrangement of the various groups and sections.

We are pleased to note, just before going to press, the enthusiastic meeting of the Engineering Society on Wednesday evening, November 4th, in Convocation Hall. The occasion was the presentation of a portrait of Dean Galbraith to the Board of Governors of the University by the undergraduates and graduates in Engineering of the University and S. P. S. The presentation was made by E. W. Stern, '84, New York, one of the School's earliest and most distinguished graduates, and the portrait was received on behalf of the Governors by Dr. John Hoskin. President Falconer, Dr. Ellis and Prof. Haultain all spoke in a happy strain. The Dean received an ovation on rising to speak, making a characteristic and witty address. The portrait is by J. W. L. Forster, who has expressed most faithfully the personality of his subject. A more extended account is reserved for next issue.

WHAT THE GRADUATES ARE DOING

Mr. W. J. Francis, C.E., who graduated from the School of Science in 1893, and who now has a consulting practice in Montreal, is at present contributing a series of papers to British technical journals on engineering in Canada. In one of these papers published in The Engineer, dealing especially with engineering at Toronto University, he has classified, according to geographical distribution and employment, the graduates of S. P. S. up to and including the class of '04, approximately 500 in all. His fiindings will be read with interest. Canada retains 75%; United States has absorbed 24% and 1% are found in other countries. With employment as a basis of classification it is found that 69% have remained in engineering, 14% have gone into contracting or manufacturing and 17% into other lines. The distribution is as follows:

Engineering:—		
Private practice and employment as engineers.	39%	
Government and municipal engineering work..	15%	
Railway engineering	10%	
Light, heat and power engineering	5%	
		69%
Industrial lines:—		
Contracting	8%	
Manufacturing	6%	
		14%
General business pursuits	4%	
Educational work and professions other than engineering	13%	
		17%
Total		100%

Meeting of Past Presidents

A rather unique meeting took place at the King Edward Hotel, Toronto, on Thursday, November 4th. It consisted of a reunion of all the past presidents of the Engineering Society in the city, together with the present president. Out of the twenty-one men who have held the position, the following responded: H. E. T. Haultain, '88-'89; C. F. King, '96-'97; W. E. H. Carter, '98-'99; E. A. James, '04-'05; T. R. Loudon, '05-'06; K. A. MacKenzie, '07-'08; T. H. Hogg, '08-'09; R. J. Marshall, '09-'10. These together with C. H. Mitchell were the guests of Prof. Haultain at a dinner in honor of E. W. Stern, who had come up from New York on purpose to present the portrait of Dean Galbraith to the University. A very full discussion took place on how the interests of Engineering at the University might be advanced, particularly in the line of post-graduate work. It was decided to push the matter of scholarships, etc., at some future time. In the meantime it was considered advisable to try to obtain equal footing with other faculties in the matter of scholarships at present in existence. More will be heard of this later.

It is interesting to note the whereabouts of the remaining presidents.

F. W. Thorold, '00-'01, is at present in Toronto, but this was not known at the time.

D. Sinclair, '02-'03, and J. D. Shields, '93-'94, are also in Toronto, but the former was seriously ill and the latter indisposed.

R. W. Thomson, '91-'92, mining engineer, passed through city the previous day, on his way to Nova Scotia to report on a mining proposition.

A. E. Blackwood, '94-'95, is manager New York office of the Sullivan Machinery Co.

G. M. Campbell, '95-'96, is superintendent, power apparatus shops, Western Electric Co., Chicago.

H. S. Carpenter, '97-'98, Dist. Eng., Department of Public Works, Regina.

Thos. Shanks, '99-'00, Department of the Interior, Ottawa.

J. F. Hamilton, '03-'04, D. L. Surveyor and Engineer, Lethbridge, Alberta.

J. A. Duff, '89-'90, J. K. Robinson, '90-'91, W. A. Lea, '92-'93, R. H .Barrett, '01-'02, are deceased.

R. A. Ross, E.E., '90, of the firm of Ross & Holgate, Montreal, a graduate of the School in 1890, has been engaged by the Faculty of Applied Science at McGill to deliver a course of lectures on the Commercial Side of Engineering, dealing with organization and operation of companies; with purchase and sale of materials; with accounting, estimates, specifications, contracts and reports. Mr. Ross' wide experience pre-eminently fits him for such a course of lectures. It is to be hoped the new curriculum in course of construction will provide a similar course at Toronto.

E. S. G. Strathy, '07, has sailed for Porto Rico. He will be on the Engineering Staff of the U. S. Government, engaged on irrigation work.

J. M. R. Fairbairn, '93, formerly C. P. R. divisional engineer at Toronto, and later at Montreal, has been appointed principal assistant engineer of the Canadian Pacific Railway.

W. G. Chase, '01, of the firm of Smith, Kerry & Chase, has removed to Winnipeg to take charge of the municipal power plant for his firm. Mr. Chase had the refusal of the position of Chief Electrical Engineer for the city of Toronto, but preferred the freedom of private practice.

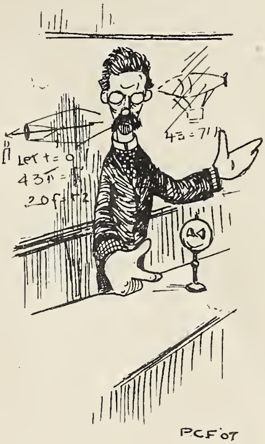
FIVE MEN IN AN AIR-SHIP

(To Say Nothing of Me and the Dog.)

John A. Stiles.

Being the true and authentic record of the culminating triumph
of the Science of Ballistics, as discovered and perfected
by several professors from the Oriental School
of Signs and Wonders.

(Note.—Man can never be considered a complete success in any line until he has sacrificed himself on the altar of his ideal, or in other words, have you the courage of your convictions to such an extent that you would even get inside of them?)



During a lecture on Light as a Force, a small glass bulb containing a miniature windmill was thrust in the path of the lantern's light and almost immediately the mill began to revolve and was soon spinning so rapidly that it could scarcely be seen. Professor Photos claimed that this was a substantial proof that light possessed a remarkable force. Very interesting doubtless, but the dear old professor fell to expanding the idea and to plastering the board with a lacework of equations until I could have thought that we were undergoing a spasm known as the Theory of Probability or wallowing in the slough of Theoretical Astronomy. I yielded to the influence of the soporific atmosphere and was soon adrift in the darkness. For the rest of the period the Rarebit Fiend and I went off on a species of neurotical jambourees.

Now in front of me were two large buildings. From the first issued a loud rumbling noise and from the second a lurid stream of light was directed high into the heavens.

I advanced and was startled by coming face to face with Photos.

"Hello!" he exclaimed, "I am glad to see you taking such an interest in your work and mine."

I wondered what that was, but concluded that he must know the answer.

"The object of my life is about realized," he continued; "a trip to Mars." He stood smiling at me in that benign, expectant way of his, his curly hair rustling gently in the night breezes. As for me and mine, I sang the Scotchman's national anthem. "Hoot mon!" I shouted, and my pulmonary artery swelled within me.

"Now see here," he said, looking off into the distance, as one who sees things the morning after, "Ballistics is the science of throwing massive bodies through long distances, and has as its fundamental law the reciprocal of the famous gravity formula vee-squared over twice gee. I discovered it in the nucleus of its germination during an exhaustive search for a scheme to get more apparatus for my laboratory."

He entered the first building and I followed. I felt as if I had stepped in at the touch-hole of some gigantic cannon, for I had not entered a building as I supposed, but a cylinder some forty or fifty feet long and about ten feet in diameter, which was pointed into the sky at about the same angle as I had noticed the light was directed. To describe it more particularly, it was a large cigar-shaped vessel which was divided into three. Professor Photos made his way to the last room and opening the lid of a large box padded with batting, remarked rather suggestively that it would make a good bed for some one soon.

At last I seemed to realize. "Can it be possible, sir," I exclaimed, "that you are really going to attempt a trip to Mars?"

"Attempt it?" he almost shouted. "I intend to do it, and you shall accompany me."

Accompany him! I almost fainted.

A quick application of two or three of the more general principles of the art of Ju-Jitsu and I found myself snugly tucked away in the padded box.

I blinked blindly and in terror at the big-eyed caricature of Photos as he bent over me fastening a few necessary straps. He seemed quite cool but my heart was beating as one who had been running a dog-churn for his wife, trying to make butter out of skim milk.

"You remember," he continued, "my telling you several times that in the ether that surrounds our atmosphere and takes up the remaining part of space not occupied by ourselves or the United States, there is comparatively little force at work. You understand, there are no wind storms or anything of that kind. Space always remains in a dead calm. I have no doubt if someone could only invent a method of creating a good windstorm in space, that it would wreck the whole universe and send stars, the moon and the planets bumping against each other like forty cats in a fit. Now, my vessel is built first of aluminum, that is the outer walls are of that substance, while next to that lies a layer of mica and inside of that a covering of asbestos. The object of each substance is as follows: the aluminum is made in such a fashion that it can be raised or opened like the slats in shutters. The mica under the aluminum, being transparent, after the asbestos is pulled down, will enable us to see clearly objects of interest, which we may pass. When we are not passing anything we can sit around the sides of the vessel and put in the time reading novels or planning for the return journey."

"But, sir," I interrupted, anxious to make time, "please explain to me how you purpose transporting your wonderful vessel into the ether or space you speak of far enough to be beyond the attraction of gravity."

"Simple as Taylor's Theorem. Newton and I have long ago discovered that the gravitational force decreases directly as the square of the distance. So you see it is merely a matter of distance. My plan is this: Behind and below this building is a large cylinder running underground for over half a mile. This cylinder is rapidly being filled with a fulminate made from the gasefication of the governors' meditations. A meter at the door registers the amount of contemplated force thus being accumulated. Then taking into account the exact coefficient of resistance, which Professor Hydros has kindly worked out for me, I have computed that it will take about steen pounds pressure to the square inch to hustle us without the jurisdiction of this globe. Then what ho! the rest is easy and I'll get my name in the *Globe.* That reminds me, I must see Mr. Marconi about a little matter regarding communication with home. You see my wife will likely be anxious."

"What about air?" I panted. "We must have air to breathe and this vessel will not hold enough."

"Do not worry about that. In the other end of this car stands a drum of vitrified air sufficient to refill these compartments one hundred and fifty times or more."

"The distance—is it not too great to attempt to cross before we shall all be dead?" I asked.

"The distance is a mere bagatelle. You will recall, doubtless, the many lectures I have given you on Light as a Force. Very well; my plan is this: Upon being shot away from the earth an immense light will be turned upon us which will increase our velocity from 15 to 29.995 per cent. per second. A little problem in acceleration for you. You see in space power gained is power retained, and a little mental arithmetic will show you that at the end of an hour's time we shall have attained a speed of seven thousand miles per minute. Then the rest will be easy. All we shall have to do will be to sit there and go, simply go! go! I have got the problem of food and all that sort of thing solved long ago."

The rest was easy, sure enough, for he put a sponge to my nose and the last thing I remembered was wondering whether I would be back in time to take a demonstratorship or not.

A frightful pain in my left arm awakened me. Surely I must be at sea. How dreadfully the ship was rolling! How dark it was! I struggled to get up but found that I was firmly bound. Now I remembered everything. I was out in space careering along at seven thousand miles a minute. There was some satisfaction in the fact that we were going pretty fast. As I lay thus musing, someone opened the lid of my box and I found myself blinking at the dazzling light of the sun. My next impression was that it was very cold in the car.

"Don't you think it's time you got up?" said Photos. "I don't know what time it is, for my watch seems to have stopped, but I shall call up Toronto in a minute. I want to speak to the Dean. I have just remembered that I have forgotten to get leave of absence and I suppose he'll be properly mad over it." He went to the end of the car and worked a telegrapher's key for a few minutes. Then a moment's wait and he began to write rapidly. "The explosion which sent you into space brought down City Hall tower, also Science buildings; all exams. off. Special meeting of Council. Warrant out for your arrest. Full page article in all papers. Keep us advised. Dean says doesn't see how he can let you go. Great opportunity working for moving picture shows when you return. Time 9.30 a.m."

"Hem," said the professor. "They won't think me so slow after all, will they? I wish the shock had killed a man I know, but that's neither here nor there. At least I mean, thank goodness I am away from him, at any rate. Now I suppose we had better wake the rest, since it is long past breakfast time."

Imagine my surprise to see him open five boxes similar to the one in which I had been imprisoned. Professor Looby yawned, stretched, looked about him, smiled good naturedly, asked if we were out of sight of earth yet, and turned over for another snooze. Professor Walkembust was already awake and anxious to be up. "Good morning," he said, stroking his hairless pate. "How are chances to get something to eat?" Professors Statish and Kemoss were not so easily wakened, the effect of the anaesthetic not having worn off yet. However, by the time the occupant of the last couch had been liberated and pacified all were ready for something to eat. The last named individual being none other than our old friend Tige, the dog. The poor brute seemed to take in the situation at a glance and gazed up into our faces with a look which seemed to say, "Well, I'm next all right, but what's the answer?"

After breakfast Looby opened a paper door and crawled up to the top of the car along which ran a huge telescope. "I shall now determine our whereabouts," he remarked quite cheerfully. His face was not so cheerful, however, a moment later when he slid down from his perch and announced that we were heading straight for the moon.

"Gentlemen, I might as well break it to you at once. Get ready for a bump, for I think there is going to be one. Even now we have covered over half of the distance between the earth and the moon."

Then followed many hours of wonderful events. We all, including the dog Tige, stood gazing through the transparent sides of the car at the objects we were passing and some that passed us. Kemoss remarked with a grim smile that most of the things we saw were going in the opposite direction to that in which we were inclined to believe they were travelling. Many times we rushed by huge masses of rock, the aluminum sides often brushing them so roughly as to jostle the car. Had they not been travelling in the same direction as ourselves they would have passed us so rapidly as to forbid our seeing them.

A white light was seen before us. Slowly we ran it down. Now we were close behind it. It was a mountain of rock at a white heat. Gradually, very gradually, we gained upon it, and as we did so we became conscious of its great heat. Like a fiend the car seemed to recognise a comrade and was diving straight toward it. The heat became so intense that we were compelled to lie upon the car floor and let down the aluminum flanges. Poor Tige seemed to scent the danger, for between his pantings he would stop to whine and look up into the faces of each of us in turn.

During all the mad race Kemoss had not uttered a sound, but just as the car seemed about to touch its nose to the rock he stepped quickly to the front, took a look, and said, "I think we had better change the air in the car. It is getting rather close in here. I do not think that there is much cause for alarm at our present situation. If you will enter the next room and close this door I will show you how we purpose defeating such fiery friends as that ahead of us." We obeyed. The snout of the car was almost among the flames when the professor opened two valves in the head of the car. A hiss—a roar—an intolerable odor. As Kemoss returned to us and we pulled open the door to receive him the rush of air from our room nearly overbalanced him. A shrill whistling from the valve on the vitrified air drum and the car was once more filled with precious air. We raised the flanges now and all rushed to the head of the car. The rock was gone, having been blown completely clear of our path. We were saved for the present at least. We could hardly avoid the thought, however, that perhaps the next monster would not be travelling with us but against us. Walkembust remarked with a smile that it would have been a quick business if our friend had been coming to school instead of going home.

It was now about twenty hours since we had been hurled into space and since Looby assured us that we would not be near the moon for another day at least, our speed having so decreased, someone suggested that we take a snooze. I did not feel inclined to re-enter my bed. It was too much like trying to sleep in one's coffin, so I imitated the example of the others and lay down with my feet towards the head of the car.

How long I slept I don't know, but I was awakened by hearing the rest of the company talking excitedly. I rubbed my eyes, got up and gazed about. We were quite near the moon now, very near it, too uncomfortably near. Contrary to our expectations, however, the bump did not come, for we shot past the satellite like a cannon ball. We were standing looking at one another wondering what would happen to us next, when the strange conviction was forced in upon me that our car was not travelling as fast as formerly and I was not surprised to hear Looby say, "I thought so. Now we are going to go back to the moon." True enough, like a shot out of a gun we swept past it again, stopped on the other side and made the return journey, though with less force. The truth of the matter was that we were virtually playing the part of a satellite to the moon, running around and around it like the gyrations of a moth about a candle flame. Our speed decreased. Once we thought we were going to run into another rock, but it proved to be only a flaming bag of gas and we shot through it, scarcely feeling the heat.

As our velocity decreased it became possible to make a more careful inspection of our new home. It was much as we had seen in magazines, spinning always with the same side to the earth. As we shot once more around it we noticed that it was bowl-shaped, the side away from the earth being hollowed out like a walnut shell. We sped back and forth about this strange satellite for two or three hours, but always getting closer and finally tripping over the edge of the bowl and soaring down like a bird. As we were nearing the ground I could have screamed with excitement.

"Down with the flanges," hissed Photos, and they went down with a crash just as the car alighted. There was a tremendous jolt that sent everything, ourselves included, into a heap at the front of the car.

Tige was the first one to raise his voice on the new planet. Something had fallen on him and he was yelping loudly. He was soon located and bounded about over everybody and everything in the dark. Then began a rummaging among the debris for the box with the tapers. We succeeded after a time in getting a light and proceeded to take stock of our mixed merchandise. The partitions and everything belonging to them had been swept away, but notwithstanding the great crash the car was even now air-tight.

Outside we could hear a light tapping on the car and directly above our heads we noticed a sound as of some one drilling. To this part Professor Statish gave his whole attention, murmuring something about the horizontal resolved part of the resultant. Mounting on a box he listened intently. The drilling continued for some time, probably an hour, when finally the professor's vigil was rewarded. The sharp point of a green-colored instrument pierced the mica. The professor immediately seized and held it and instructed me to mount on his shoulders and ascertain if possible, by peering through a crack in the flanges, what sort of a creature was doing the damage. By the aid of a piece of glass I was at length enabled to catch a glimpse of the figure, which was crouching on the roof of the car trying to withdraw the tool. It was a creature about four feet high, pearl-colored and shone in the sun, as if it had been highly polished. It was proportioned exactly like a man and I noticed that it had no hair. In fact there did not seem to be room for any hair, for a row of rabbit-like eyes ran completely round its head. At first I was inclined to think it had no ears, but a moment later I discovered that it had one nearly as large as a saucer placed exactly on top of its head.

The professor now released his grip and the boring tool was jerked out, but immediately upon its being withdrawn there was a rush of air. I saw the pearl-colored creature duck his head as if to listen to the noise and then away he flew high into the air kicking and squirming. The hole was quickly closed by placing pieces of paper over it.

Descending from our perches we now held a council of war. There was no doubt about it, the Moonites were evidently very curious or else were openly hostile.

"I tell you what," said Statish, "I know something about the horizontal resolved part of the resultant. When that little beggar drilled an opening through our roof the air cooped in the car puffed him high sky. Well, I advocate cutting similar holes on all sides of the car. Let us cover them with pieces of paper and then raise the flanges. As soon as those creatures see us they will likely make a charge and clamber all over the car and when the car is well covered with them we will pull away the paper."

"A very good idea," assented everybody, "though it is strange that you should have thought of it since your science only deals with stationary bodies and that makes a noise like dynamics."

"You're all wrong," said Photos. "It makes a noise like the Science of Ballistics and I am the one that should have thought of it."

"Well, well, don't quarrel, gentlemen. Let's get to business," said Walkembust.

Immediately we began cutting small holes in the mica with our knives and soon had one hundred and fifty holes made and each covered with several plies of thick brown paper.

"Now, up with the flanges." Up they went and the car was once more flooded with sunlight, which so affected our eyes that we were unable to see for some moments.

When our eyes had gained sufficient strength to bear the light, a scene was unfolded before us which was somewhat startling. At two or three hundred yards distance stood about a thousand of the pearl-colored men, glistening like so many granite tomb-stones. Picking up a telescope, I directed it towards the crowd. It was composed of beings similar to the one we had first seen. Their hands and feet were shaped like cups. Suddenly they turned and rushed towards the car.

As they came forward we perceived that they each carried strange instruments which resembled egg-beaters. They were rapid runners and soon reached the car, clambering over it like a cloud of locusts. The mica was several inches in thickness and while they were boring we charged the car well with air. Then stationing ourselves about the car we began jerking the paper from the holes, replacing the pieces immediately. As each aperture was uncovered there was a zip of the escaping air and one and sometimes two of the Moonites were hurled high into the air, to alight some twenty or thirty feet away apparently uninjured but not anxious to repeat the experiment. Pop! pop! pop! Away they flew like toy balloons, alighting some head first, on their backs or rolling over and over like empty baskets chased by the wind.

Photos now unlocked the sliding door and for the first time in six weeks we stood on terra firma. It occurred to me that Tige might like a scamper as well as ourselves, accordingly I opened the door and let him out.

"Phew! we should have tied a stone to Tige to keep him down," said Kemoss.

Big Tige went crazy for the time being. With two great bounds he was close to the group of Moonites. One more and he had sailed completely over their heads. He turned quickly and jumped at them again. Whether he had made up his mind to devour the whole tribe or not I cannot say, but at any rate he had to exercise great patience before he could get near enough to even get a sniff at them. Each bound sent him twenty yards farther than he intended to go. Nor could he seem to understand, for he flew over and over the terrified creatures, and his barking sounded like the roar of a hundred cannon. At last it seemed as if the Moonites could stand it no longer and we were surprised to see them all standing on their heads, their one ear buried in the loose yellow sand. We noticed that as we spoke to one another our voices sounded ten times louder than was natural and over and above all sensations was an all-pervading odor of Welsh rabbit. At times it was almost stifling. The ground on which we were endeavoring to walk was like flour but was a kind of chrome yellow. We had scarcely time to consider this when Tige, having given up pursuit, came sailing back to us like a toy balloon in the breeze. With a frightened yelp he went careering over car and all. He now seemed to have an inkling that something very peculiar was the matter and turned and commenced crawling very slowly along the ground to us. We caught him and tied him to the car door. Our enemies had now resumed their former upright positions and began rubbing and pushing one another with their cup-like hands, but we heard no sound from them. Considering that they had learned enough of our powers, we ventured to move a little away from the car. "Great guns! here they come!" shouted Photos, his voice almost deafening us. "What shall we do? We have not a thing with which to hit them and we are cut off from the car." However, as we hesitated the solution was shown us by Tige. About a hundred of them had made toward him. He rose to the occasion and although tied to the car succeeded in raising car and all in a great bound. Finding that he could not fight thus encumbered he contented himself with waiting for the others to assail him. Ten of the bravest charged him with their egg-beaters. Waiting until they had advanced to within a few feet of him he barked. That was enough. The dog's breath was too much of a gale for the pale faces and they fell over one another in great confusion. What happened to Tige after that we were unable to say for we had troubles of our own. Hundreds of the Moonites charged us. Professor Statish drew a long breath and stepping forward greeted ten or fifteen of them with a tremendous puff, which sent them all down like nine-pins. It was my turn next. About twenty of the many-eyed creatures came at me. I filled my lungs as I had seen the professor do, but alas! I could not keep from laughing and exploded long before my foes could reach me. It was Kemoss that did the mischief. He was down on his hands and knees trying to bark like a dog and succeeding very indifferently. A moment more and we were in the midst of them. They seemed numberless, climbing over each other in their desire to get at me. Help! Help! I screamed and my voice cleared a space around me for a moment. Then they were at me again and stabbing and drilling at me with their egg-beaters.

It was Kemoss that saved the day. He had fought his way back to the car and returned with a drum of compressed air and a hose. The rest of the battle was as easy as watering the lawn. Swish! Swish! and there was a space clear in front of us. "Save Walkembust!" shouted Photos, who was now struggling toward us, "he is down!" We shouted and dragged the hose after us as we blew a path to where we had last seen him.

Swish! Swish! went the nozzle and the professor lay before us. His face was completely covered with minute red specks. We turned the air in his direction and greeted him with a refreshing breeze that soon revived him.

We could no longer reach our enemies by means of the air blast, so as a last resort I slipped back to the car and let the dog loose. Just the chance that Tige wanted. Barking savagely he rushed towards them, jumping over and over them but occasionally lighting right in the midst of a frightened crowd, knocking them right and left. Within five minutes we made out a party of our assailants coming towards us. They advanced running for some distance, then falling to the ground began working their way towards us on all fours. Occasionally they would stop and wave their handless arms demonstratively in the direction of the dog. At last we understood their meaning and whistled for the dog and chained him up.

We then made signs that we were not anxious to resume hostilities if they would throw down their egg-beaters, which they promptly did and advanced fearlessly towards us. The smallest individual among them advanced at once to Professor Walkembust and began gently to stroke his wounded face and bald head. The red specks left immediately and we were more than surprised a few minutes later to see a luxuriant crop of golden hair and a beard appearing. He was jubilant and was constantly thereafter coaxing us to tell him what he looked like.

It was not long until Walkembust's instincts began to assert themselves and he started walking across country, followed at a respectful distance by the Moonites. We crossed great fissures in the loose yellow ground by simply leaping them, the Moonites going around. Walkembust seemed greatly perplexed at the rock formations and when we questioned him as to their technical name, he said that as time went on he was more and more convinced that it was a species of rock which is usually found in table lands and called Limberg-Silurian. We crossed the bottom of the bowl, so to speak, and were now crawling laboriously up the side to the edge of the dish when I slipped and fell. To save myself I dug my heels deep into the earth and went ploughing down the slope. I was somewhat behind the rest of the party now and was about to redouble my efforts to reach them when the earth beneath my feet smelt so strongly of Welsh rabbit that I yielded to the temptation to taste it. My suspicions were confirmed but I said nothing to anybody.

Having rejoined our party we proceeded up the slope, reaching the top just as the sun was setting behind us. From our new point of vantage we could now make out that which we had seen before our car landed, viz: that the moon was shaped like half a walnut shell. The edge of the shell was fringed with a strange kind of string-like grass, which very much resembled cotton rope. Kemoss, seated in the midst of this, had pulled a pad out of his pocket and was making a rather careful sketch of the United States and Canada. I asked him if he thought that he could see Toronto. He said he didn't, but ventured the remark that he thought he could see Chicago and pointed to a black mark beside a lake. I looked a moment and asked, "Are you sure it isn't a volcano?" "Quite sure!" he rejoined; "I know Chicago well."

The outer surface of the moon looked like a sheet of coarse canvas that had been painted yellow, something like the old-fashioned bass-wood hams.

Being somewhat fatigued with our journey, we reclined in different postures on the brow of the hill, now watching the affairs of earth and ever and anon looking back into the darkening valley behind us. We were some distance from our car and I for one was ravenously hungry. I whispered this to Professor Walkembust so as not to disturb the rest with unnecessary fears. He looked at me and smilingly whispered back: "If you are hungry why don't you eat? You are fond of cheese, are you not?" I admitted that I only cared for old cheese. "Well," he continued, "this should be old enough for you," and he knocked a corner off a neighboring rock and began nibbling at it. I followed his example. Soon the secret was out and all the party were gorging themselves.

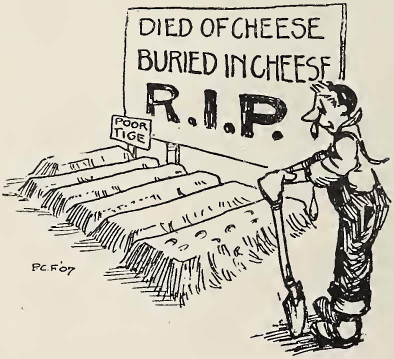
The moon, then, was nothing more nor less than a gigantic cheese. As the Moonites observed us eating the ground upon which we stood, one of them advanced to my side and stooping down touched my forehead gently. I was surprised at the sensation. A quiver ran through me and an impresion in my mind rapidly shaped itself into words which said, "Do you like it ?" The Moonites, then, had no language, but communicated their thoughts from one to the other by the "touch method." Then followed a long conversation, for I discovered that this creature was able to read my thoughts without even so much as touching me. I always was a plain thinker. Professor Looby had adopted different tactics. He had one of the handsomest Moonites on his knee. He smiled at it and it smiled back and fed him with choice pieces of cheese gathered from the neighboring rocks. The dear little creature indeed had a most kissable looking mouth but I didn't think that Looby would do it, but he did. I looked towards the young Moonite and in its row of eyes distinctly read, "Please tell him not to do that again. It tickles. Oh, isn't he awful!"

If the moon was cheese, then this rope-like grass must be the rind. Calling one of the Moonites to me, I elicited the information that once the moon was round but that it had all been eaten away until now little more than the mere shell of the original moon remained.

We spent the night on top of the edge of the bowl and in the morning were awakened from a short nap by hearing Tige's barks. Convinced from the noise that he was making that there must be something unusual the matter, we hurried back to the car and a sight greeted our eyes that was more than ordinary even for this strange country. The car was completely surrounded with the most peculiar looking animals. They looked like immense white snakes. They were covered with long, straggly hair and deep wrinkles. As we approached waving our arms and shouting they jumped away. I say jumped away because that was what they literally did, for their mode of locomotion was beyond description, though done something after the following fashion : When one wished to change its position it placed its head on the ground, arched its body and brought its tail close to its head, then with a tremendous bound went spinning through the air. As we were gazing at them in terror I noticed Walkembust smiling. "Don't you know what they are?" he asked. We all admitted that they were a new variety of snake to us. "They are not snakes at all," he laughed. "They are skippers."

The following days were all filled with pain and trouble. We had nothing but cheese and fresh skippers to eat. First Tige took sick and died; then Looby startled us by saying that his nose itched so terribly that he could scarcely stand it, and we realized that it was the result of eating too much cheese. Oh, it is too terrible to tell in detail. One by one all of our party was wiped out, dying of that terrible disease known only in the moon, "itchy nose." Died of cheese and were buried in cheese.

As for me, when Photos died, the thought that his examinations would all be called off was too much for me and I awoke from my dream to find the lecture on Light as a Force still in progress and the board about a foot deep in equations.



Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 DECEMBER, 1908 New Series Vol. 2, No. 2

ADDRESS BY MR. E. W. STERN

NOVEMBER 4th, 1908.

On the occasion of the presentation of portrait of Dean Galbraith to the University.

This honor conferred on me by my fellow graduates and the undergraduates in Applied Science of the University of Toronto is one which is most flattering, and which I most deeply appreciate and can never forget. No greater pleasure could come to me, than to return to my old home and old college after many years, to be with you all and to be asked to participate in such an event as this, the public expression of the appreciation in which our beloved preceptor is held.

There might have been selected one far more worthy of this honor and more able to express eloquently the thoughts which an occasion as memorable as this should bring forth, but none more in sympathy with it, nor more impressed with the sterling worth of the man in whose honor we have met this night.

I do not propose to speak a eulogy of Dean Galbraith, because as we are all one of his family, so to say, it might perhaps not be in good taste, and besides a parent should not be praised too much by his children, it might spoil him, and he might take advantage of us; nor to refer, except briefly, to the evolution of the School of Practical Science into the Faculty of Applied Science of the University of Toronto and its steady growth under his fostering care, with the loyal support of his able colleagues, from its modest beginnings, some thirty years ago, to the great institution it now is, because such a recital would deal practically with the commencement and development of technical education in this province with which his career has been most intimately associated, and there are those much better qualified to speak of this than I; but rather to try and express what we, his old pupils, know of the man, and our appreciation of him and to tell you of those sterling qualities of mind and heart, the modesty, the thoroughness, the patience as a teacher, the kindliness and the human attractiveness of his personality, the interest in the welfare of his old pupils, all of which has so endeared him to us, and has had such a strong influence upon our lives.

My first acquaintance with him goes back a long, long while ago—twenty-seven years—when most of the young gentlemen now before me had not yet made their appearance. I called at the old brick school-house to ask him about the studies which were taught in the School of Practical Science. My notions about the profession of civil engineering were very vague, and I asked for enlightenment. As a result of our interview, I was so taken by some indefinable quality in his personality, that I decided to enter this school and learn civil engineering.

It was then a very modest school, only three students in the third year, three or four in the second, and about one dozen of us freshmen. The faculty in Engineering consisted of Prof. Chapman, Dr. Ellis, Dr. Pike and Prof. Galbraith, and we had a few hours a week in University College, under Prof. Loudon and Baker. All the Engineering lectures were given by Prof. Galbraith as well as the field instruction in surveying, and for three only too short, happy years, he led us all the way through the mysteries of mechanics, thermodynamics, descriptive geometry, hydraulics, etc.

We were indeed fortunate in those days on account of the small size of the classes in having so much of our preceptor's attention; we could not help but learn under him, and learn to think for ourselves. The class was thoroughly in earnest in its desire for knowledge, for such was the inspiration of his teaching. His patience was untiring and he never hesitated to go over and over again, a subject which we could not understand, until we had it. While he maintained discipline, it was done without harshness, his teaching was thorough without being pedantic. He impressed us with the importance of getting at the bottom of things and of trying different methods. His lectures were informal, his methods not academic. He would put down a difficult problem on the blackboard, and sit down and think it out with us. If the problem were one involving a knowledge on our part, say of certain theorems in calculus or algebra which we were supposed to know but which we were not clear about, he would go back and drill this into us before proceeding with the problem in hand.

I can recall to this day, how persistently he kept at us until he made us understand that in a beam, the neutral axis corresponds with the centre of gravity of the cross section, and that $\frac{M}{I}=\frac{p}{y}$. Rankine (peace to his ashes) was even made plain. He untangled many of his knotty theorems. As I think back, I can still remember away off in the distant past something about the internal stress, which we underwent to understand the ellipse of stress, adiabatics, isothermals, and to draw the shadow which a cone casts on a parabaloid of revolution. He really did clarify in our minds these mysterious things.

The lectures would be enlightened with flashes of keen humor. I remember that once in expounding the theory that the forces acting on a body are in equilibrium when it is either at rest, or in motion through space at uniform velocity, I asked the question, "What would happen if the body struck me?" The answer came quick with a mischievous twinkle of the eye, "Well, let us see—if it struck your head, it would depend on its quality as to whether it rebounded, or went through."

His technical qualifications and breadth of view were such that we soon realized we were under the guidance of a master mind. It was, however, the human quality of the man, his fineness, his way of thinking and talking straight, his kindliness and interest in each of us and his sympathetic nature, which appealed most to us. He was a man, every inch of him, and one of nature's own noblemen. He never preached at us, nor did he ever talk about what was right or wrong, but somehow or other, remarkable to say, we absorbed ethical teaching from him. I have spoken with many of our graduates, and they all agree with me in this;—we seemed to feel what he thought was the right thing to do.

He was not only popular with us his students, but he was appreciated by all sorts and conditions of men. The Ojibwa Indians call him by a name which means "The Little Chief with the noonday face." I recall personally, a suggestive incident bearing on this phase of him. Twenty-six years ago, during my summer vacation, I was on a surveying party in Nipissing; one night our party were encamped near a Hudson Bay post called Fort McLeod, at the mouth of Sturgeon River. In talking with the factor, whose name I cannot just now recall, he asked me if I knew a little professor from Toronto—John Galbraith by name. I told him that I did know him and that I was then studying under him. He said to me: "He is the finest man I have ever met, he tells the best stories—I would like him to visit here again. You come with me and sleep in a bed to-night," and we drank the professor's health from a black bottle, and thanks to him, I slept in a bed that night, the first in four months.

There were five of us who graduated in the class of 1884, a striking contrast with present times. I shall never forget his farewell address. Calling us together, he told us that now having completed our course at the school, we must start out in the world with the idea in our minds that we knew nothing whatever about engineering, and should commence our practical work at the bottom. It was characteristic of the man's modesty and thoroughness; never was better advice given, for we started out in the world with no false notions of our importance, and worked our way up gradually without friction.

Those of our younger graduates whom I have met in recent years, as well as the older ones, have nearly all appeared to me as having some certain characteristics in common, namely, thoroughness and modesty. I know of none who have been failures in life.

After leaving the school his personal interest did not cease, for he looked upon his old students as his children. My own correspondence with him has been kept up steadily during the past twenty-five years, and so it has been with many others.

Dr. Galbraith brought to his life's work a rare fitness for it, for besides the personality which I have spoken of, not only were his academic attainments of the highest, but his practical experience in his profession, in railroad work, on surveys, and in the shops was most thorough. His broad experience, therefore, enabled him to separate as it were the wheat from the chaff, in our work, and temper theory with practical experience. He impressed us with the fact that while theory was right as far as it went, we were liable to forget some very important things in our premises, and that therefore we should always scan our conclusions from the perspective of common sense, always seeking for and considering carefully, the results of practical experience.

Had he chosen to follow the practice of his profession rather than teach, he would undoubtedly have been, before this, at the top of his profession in Canada. Only recently, as a member of the Royal Commission on the Quebec Bridge disaster, together with his able colleagues, Messrs. Holgate and Kerry, he labored most indefatigably without cessation for eight long months, and the report submitted by this commission was characterized by the leading technical journals in the United States as being the most able, thorough and valuable that has ever been published, in any language, of a great engineering disaster, the lessons of which, not only from the technical standpoint, but from that of organization, morale and business methods, are so clearly set forth as to make it a most valuable contribution to engineering literature and worthy of the careful study of any engineer, no matter in what special lines he may be working. I may note, too, that in this report, while the facts have been most clearly set forth, the human spirit of charity and sympathy with the unfortunate engineers upon whose shoulders the responsibility for the disaster rests, permeates it.

Of this commission, a colleague, Mr. Kerry, formerly a professor at McGill University, and now a very prominent consulting engineer, who had been closely and intimately associated with Dr. Galbraith for months, told me that he was one of the most likable men he had ever met and asked me if we, his old pupils, realized how big a man he was. Very quickly I reassured him on this point.

I will digress a minute to quote further what Mr. Kerry has to say about him from an article in Engineering News, published a few months ago, when Dean Galbraith was elected president of the Canadian Society of Civil Engineers. He says:—

"To the development of the School of Practical Science Dr. Galbraith has devoted the whole of his time and abilities, consistently refusing to undertake professional work as a consulting engineer whenever it was likely to interfere with his duties as a teacher. The School of Practical Science is to-day the largest and most rapidly growing engineering school in Canada. This, while in a measure due to the great prosperity of the Province of Ontario, must in large part be credited to the work that has been done by Dr. Galbraith; for the successive classes of graduates have recognized the thoroughness of their training, the simple devotion to duty of their professor, the soundness of his professional knowledge and the manliness of his personal character so fully that it is questionable whether any other engineering school on this continent gets such enthusiastic advertising and such active personal support from its own graduates. It is characteristic of the man, and of his estimate of his own attainments, that he has repeatedly refused permission for the publication of his lectures and has contributed but little to the sometimes too-swollen stream of technical literature. Dr. Galbraith's work since 1878 may be aptly described as that of a fashioner of tools which have been widely used by other men in the construction of the great engineering works of Canada; the standing of the graduates of the School of Practical Science is evidence of the thoroughness of his fashioning."

It is quite evident from this article that Mr. Kerry, like all of us, has been unable to resist hypnotic influences.

As I have already said, there is no question but that Dr. Galbraith would have become a leader in his profession, had he chosen to follow it. In fact, his ethical and technical qualities would have made him a leader in whatever line of work he would have pursued, for his personality is such as to inspire confidence in those who might have availed themselves of his services, and also, would cause those who were under him to work most loyally and efficiently for their chief. But he could not have become greater than he now is. His service to the state and society from his long years of steady, devoted adherence to his life's work has been invaluable. He would have been wealthier without doubt, but he is one of the few who, having placed duty above material things, has set an example for us all.

The growth of the Faculty of Applied Science has been phenomenal. In thirty years it has grown from about 30 in all the classes to 770. This great increase has involved a tremendous amount of work on the part of the faculty and its leader, for not only was the great increase in numbers of pupils to be taken care of, but these past thirty years have been most prolific in advance in engineering science, and the School under his able leadership has kept fully abreast of the times, so that now it stands second to none in America in thoroughness and efficiency and ranks among the leading technical schools of the world.

The great success of this institution has undoubtedly been due to Dr. Galbraith, but we give full credit also to the very able, efficient and loyal support he has had from his colleagues in the faculty, and to Dr. Ellis in particular I may refer as being one of the old guard whom we remember most pleasantly and gratefully from the old days.

Dr. Galbraith's life furnishes an object lesson to every one of us—the value of thoroughness, modesty, and human sympathy in all the walks of life; and although all cannot be at the top of the ladder, we still can be steadfast and conscientious in our day's work, and above all, be respected wherever our lot in life should happen to fall.

We, his old pupils, are his life-long friends. We owe him a debt which can never be repaid. We wish him many, many more happy years of life and usefulness, and we give him our blessings.

This portrait, the work of Mr. J. W. L. Forster, is the gift of practically all the graduates and undergraduates in the Science Department, and our sincere thanks are due him for the faithful and sympathetic likeness which he has produced.

As marking the anniversary of the thirtieth year of Dean Galbraith's connection with this institution, and as a small token of our appreciation of his services to us, we take great pleasure in presenting to you, sir, for the University of Toronto, this, the portrait of one of its most gifted and worthy sons, and of one of its most beloved preceptors.

ADDRESS—ROBERT MOND*

Gentlemen—Principal.

Your Professor Haultain has requested me to address a few words to you, a request which gives me peculiar pleasure to be able to accede to.

You who have assembled here from all parts of the Dominion in order to acquire the knowledge requisite for the development of the many and varied mineral resources of the northern and greater part of this Continent are squaring your shoulders to take up a burden whose magnitude and whose importance are scarcely to be over-estimated.

All the faculties with which your forbears and surroundings have endowed you will find scope for their widest development. Only by your whole-hearted devotion and attention, accompanied by reverence, both to those who teach you by word and by letter, will enable you to worthily prepare yourself for your life's work.

Those of you who are preparing yourselves for mining will have to acquire a moral and mental probity and rectitude such as is demanded of few of your fellow mortals. On your opinion, though not directly expressed for publication, not only fortunes but the weal or woe of widows and orphans may depend. You will be responsible for the welfare of many individuals of various types and nationalities. You will be held responsible for the safety of irresponsible subordinates. And proceeding to technicalities you will have to recognize the occurrence and size of the ore deposit, determine its position, decide its development, the correct system of drainage, the methods of concentration, of roasting and smelting, possibly of refining, and the arrangements for transportation. This involves a knowledge of geology to determine the stratification and geotectonic structure of the environment, mineralogy to enable you to identify your minerals, chemistry to enable you to assay your ores and understand the theory of your smelting process, the mechanical parts of physics to understand the principles of your concentrating processes; mechanical engineering to keep your plant running; electrical engineering, where electricity is available; civil engineering for your methods of transporting, and architecture, as it applies to the buildings which you will have to erect.

It would not be humanly possible, and no one would expect it of you, to be pastmasters in the formidable list of different branches of knowledge I have thus enumerated; but the more you know of all these branches, and especially the more efficient you are in any one of them the more useful and efficient will you be in your future career.

And here let me warn you. You must not anticipate that the few years you will spend at this University will enable you to attain to this knowledge. That is not its object. But you will be taught and you will acquire the system and method which will train your mind to assimilate this knowledge from hour to hour and day by day, when you have said farewell to your Alma Mater, and as you advance in years your thoughts will turn in deep and earnest thankfulness to those who have aided you in your own evolution.

---

*Delivered before Mining Section of the Engineering Society, November 5th, 1908.

You will be called upon to go forth to the uttermost corners of the earth among strange people, and stranger conditions, to examine strange propositions. You will be unaided, unguided and unchecked, surrounded by people whose self-interests may be diametrically opposed to yours or those of your employers.

You will be exposed to personal discomfort, if not danger, to the wiles of the unscrupulous, and to the facile lie of ignorance. You will have to read human characters and learn to use your enemies as well as your friends. You will be liable to maligning, overt or dissimilated attempts at corruption; hence I say to you that you require a code of honor, a standard of morality higher than is generally demanded of mankind.

In the management of men there is only one rule which is universally accepted, and that is an absolute fairness and justice, well designated as square dealing, with those one employs. All favoritism is as disastrous to an employer of labor as it ever was to the proudest monarch history records.

A thorough knowledge of geological principles will prevent you from searching for one where it could not possibly occur, it will give you valuable information in regard to folds and faults, but it will never tell you whether the ore is payable.

The use of mineralogy in enabling you to properly classify your ores is self-evident, but chemistry is your most important helpmate.

It tells you whether your ore or your rock goes on the dump, whether your stopes are worth working, whether your tailings are not richer than your ore, whether your water corrodes your pumps and boilers and whether your coal is not heating air instead of water. And in smelting and refining you are dealing with purely chemical reactions. There chemistry will tell you whether your cyanide runs down the drains or your metals away with the slags, whether your water is fit to drink or your air fit to breathe; and chemistry not only warns you, but also tells you how to rectify any error thus made.

In concentration plants, either dry centrifugal magnetic or wet, with or without oil, the physical properties of matter are of the greatest importance. Your processes depend on graduation both of volume and weight and you will find by careful and conscientious experiments, that concentrating plants and concentrating plant manufacturers' catalogues are not synonymous.

One of your most important and conscientious tasks will be that of sampling. Here again it is only by fully understanding the underlying principles that you will be able to adapt methods to your materials which will give you concordant results.

You will have to be expert surveyors and neat and quick draughtsmen or your experience may tally with that of the Roman engineer who, in the second century A.D., having to drive a tunnel for the conveyance of water through a mountain in the ancient province of Mauretania (the present Morocco) surveyed the mountain and started to work from each end. After some time the contractor was sent for by the Governor of the Province, as the work showed no sign of completion, and it was found that each party of miners deviating slightly to the side had nearly driven two tunnels through the mountain.

Of mechanical, electrical and civil engineering you will acquire the rudiments and you will have many opportunities of perfecting your knowledge by subsequent experience. Mining engineering proper you can only learn in a mine. But your own personal experience will of necessity be limited to special cases, and you must seek every opportunity, both by reading and seeing, to acquire as extended a knowledge as possible.

The correct type and use of rock drills, the most advantageous methods of blasting, the correct methods of supporting the roof of the mine, the timbering of shafts and of levels, the methods and means of extracting the ore, the determining of the boundaries, all so varied in application, are still reducible to a few leading principles which you will have to acquire.

And as regards exploration, the first necessity for this is an adequate knowledge of similar ore deposits situated in the vicinity, or in other parts of the world, which from analogy enable you to understand their general mode of occurrence, their recognized methods of extraction and their probable origin. We are not endowed with a sense which enables us to see through a piece of rock, and the mechanical means which have so far been elaborated—magnetic surveys, diamond and other drilling, stripping cross-cut pits and shafts are both expensive and laborious methods of acquiring uncertain information. You must consequently be well acquainted with the use and abuse of these methods so that you can employ them as useful tools for aiding your judgment and keep continually aware of their strict limitations.

In whatever branch you may be occupied one thing above all others will be required of you, and that is, that you embody your observations or findings in a clear, logical and concise report. To few is given the gift to do so, therefore the greater the necessity of acquiring the habit of study. It is of equal advantage to the writer and to the recipient, as it compels the former to recapitulate and arrange in his mind the data for which he is responsible, whilst for his superior or employer the reports are the best means for gauging his capacity and character irrespective of the value of the report as regards the matter in hand.

A knowledge of book-keeping and store and stock-keeping should be acquired. The methods are simple, and proper organization immensely facilitates one's work and prevents waste and worry.

And, finally, if you have discovered and developed a mine, extracted, concentrated under economical conditions a valuable ore, this is only the first step in making the metal therein contained available for human use. It now has to undergo a refining process and be converted into a shape such as is required by the market.

This involves an entirely new state of affairs. Up to this stage all the necessary operations have had perforce to be carried on in close proximity to the mines so as to reduce to a minimum the transport of waste material.

In the refinery the ore is only one of several raw materials. It is usually the most valuable, and hence best able to stand heavy transportation charges. Others, such as fuel, fluxes, power, acids and other chemicals are more bulky and mostly less valuable than the ore. Proximity to the readiest means of transportation giving access to the world's markets for the finished products and bye-products will be the determining factor of its location.

Refineries are also associated with a large number of cognate industries who draw upon the refinery for their raw material. Their proximity not only reducing cost of transporting, but also enabling the consumer to speedily obtain rectification of errors and attention to his individual requirements an element of the utmost importance in the rational and logical development of an industry.

Those of you who will hereafter be associated in the manufacture of the numerous alloys of iron, will learn the part the composition of your ore will play in the subsequent usefulness of the pig iron produced. How phosphorus silicon, manganese, chronium, tungsten, titanium nickel and vanadium, not forgetting carbon will essentially alter its character. Even the student of history and political economy will be surprised at the overwhelming importance the use of metals has played both in the ancient and the most recent times, even as the neolithic stone age was conquered by copper, this by bronze, and that by iron and steel. We find that in the 17th century the adoption of coal by the iron industry abolished the iron industry of the South of England, and drove it into the coal fields. Mr. Gilchrist Thomas' invention of the basic, instead of the acid lining of the open hearth furnace enabled Germany to build up its immense iron industry on the phosphate iron ores of the Rhenish Province, Westphalia and Luxemburg. The celebrated Saracenic Damascus blades of the time of the Crusaders owned their excellence to an admixture of nickel which now again is used in our most powerful engines of war.

The search for ores and refining of metals provided one of the earliest means of human interchange. We learn that Egyptian Kings of the 3rd Dynasty about 4,000 B.C. secured copper ores in the Sinai peninsula. We have plans and workings of the time of Seti of the XIX Dynasty about 1300 B.C., Crete and Cyprus grew rich on copper, Athens on the lead silver mines of Laurin. The Etruscans based their industry on their copper and tin mines, the Phoenicians sought gold in Africa and tin in Cornwall. The Romans worked tin, gold, silver, lead and copper mines over the whole of their Empire up to its confines in Northumberland and Spain, and in turn the Spaniards overthrew the Empire of the Inca's and Aztec's in their search for gold on the South American Continent. German miners brought over by Queen Elizabeth revived the mining industry of England, and thence the mines of the most distant parts of the world, from the Yukon to Tasmania, have had to yield their share of the world's riches.

And through these ages the advance of metallurgy can be traced through the successive recognition of the elements of which middle ages are composed. From the middle ages onward before which only the four elements of Aristoteles were admitted each succeeding generation succeeded in isolating, and hence learning to separate from additional metal or element, and this process is so far from being exhausted that my friends, Lord Rayleigh and Sir William Ramsay, only recently succeeded in finding in ordinary air a new constituent gas, organ which constitutes nearly one-hundredth part of its volume, whilst subsequently Sir William Ramsay has succeeded in finding some three more. Uranium has yielded radium to Madame Curie, Bismuth polonium and thorium actinium, whilst my friend, Sir William Crookes, has still quite a number of undefined rare earths of the Didymia-Yttria type awaiting complete isolation.

Complete analysis of the metal-bearing constituents of the Igneous rocks have taught us of the wide dispersion of the elements in the earth's crust, whilst the recent application of such rare elements as Thorium and Cerium to the incandescent gas mantel, as discovered by Dr. Auer, from Welsbach, plainly teaches the impossibility of predicting the useful application of an obstruse scientific discovery, which is equally borne out by the recent industrial application of Osmium and Tantalum to electric lighting.

These recent discoveries should be auguries of great hope to all of you, demonstrating the great harvest that awaits a reaper and which can only be garnered by undeviating devotion and application to the subject of one's study. No reaction is so obstruse and no object so insignificant that a diligent study will not yield a rich reward to the searcher. The collection and classification of a few petrefactions and fossils has enabled us to actually determine the relative successions of the layers of the earth's crust, and just as finding a few fossils characteristic of the strata underlying the coal will convince us of the futility of further search for coal similarly the determination of the beds overlying it will give you the desired indication.

The way which has to be traversed from the experimental determination in a scientific laboratory to the practical application on a large scale under technical conditions is a long one and fraught with many difficulties. The peculiar aptitude of mind which is best adapted for solving scientific problems in the laboratory is only very rarely accompanied by the power of expansion and assimilation required by the new set of factors involved by operations on a technical scale. Hence no new process fresh from the laboratory can hope for success unless those who take it in hand have both knowledge and perseverance which will enable them to laboriously and systematically grapple with the difficulties as they arise, and use their accumulated experience to the solution of the problem. It has often been said that we only learn by failure. Unfortunately in technical processes no records of the failures are extant from which we might learn what to avoid. Hence we see many promising processes involve the ruin of their inventor, whilst in subsequent years the same process may become one of world-wide adaptation, and if we search for the cause we frequently find that another invention of an entirely different nature has bridged a gap or made some operation economically possible. I might give you as an example the improved treatment of the extraction of gold from the ores, first by the introduction of the cyanide process; secondly, by the application of this process to still poor and formerly unremunerative ores by the adoption of a new and more economic crushing apparatus, namely, the tube mill instead of the battery stamp. Neither of these have any reference to the cyanide process, yet a more efficient crusher has materially increased our resources. I could cite you many similar examples, and also the converse, where some new invention has facilitated a large number of known processes such as application of electricity as a motor power to scattered units, or to the application of steel specially prepared for armour piercing shells to the jaws of the stone crusher, or the application of ice-making machinery to shaft sinking and quicksand.

In this connection I may be permitted to refer to my father's discovery of the extraction of nickel from its ores by the nickel carbonyl process.

My father, Dr. Ludwig Mond, had devised a method for obtaining hydrochloric acid directly from the ammonium chloride, which is a by-product of the ammonia soda process.* The method consisted in passing the vapour of NH_4Cl over magnesia, and the apparatus was fitted with nickel valves, because this metal is not acted upon by the vapour of NH_4Cl. On the laboratory scale these valves worked perfectly, but on the manufacturing scale they became covered by a black crust of carbon and became leaky. This was traced to the presence of a trifling quantity CO in the large scale plant and this led to the investigation of the action of nickel on carbon mononide. This finely divided nickel reduced by hydrogen at a temperature of 400°*C* was treated with CO in a glass tube at varying temperatures for a number of days, and was then cooled down in a current of CO. To get rid of the poisonous CO the gas was lit as it escaped from the apparatus. When the apparatus was cooling down the gas became luminous, and increased in luminosity as the temperature fell below 100°*C*. On a cold plate of porcelain put into this luminous metallic spots were deposited similar to the spots of arsenic in Marsh's test. On treating the tube through which the gas was passing a metallic mirror was obtained and the luminosity disappeared. These mirrors were found to consist of pure nickel. The best results were obtained by treating nickel with CO at 50°*C*, and by passing the gas so obtained through a tube cooled with snow and salt liquid nickel carbonyl was obtained, freezing at —25°*C*, boiling at 43°*C* and decomposing at 150° into its components, CO being set free and nickel being deposited as a dense metallic film on the side of the vessel in which it is heated. A large plant was erected near Birmingham to utilize these discoveries for the production of nickel from Canadian nickel copper matte from Sudbury.

The matte which contains 40% nickel and an equal quantity of copper is carefully roasted to drive off sulphur, and is then subjected to the action of water gas or producer gas rich in hydrogen in an apparatus called a "reducer", at a temperature never exceeding 400°*C*. From this apparatus the substance now reduced to the metallic state is carried to the "volatilizer", in which it is subjected at a temperature not exceeding 80°*C* to the action of CO gas.

The CO gas charged with nickel carbonyl leaving the volatilizer is passed through tubes or chambers heated to 180°*C*, in which the nickel is deposited and the CO is used over again.

But the main lesson brought out by these considerations is the interrelation of all branches of human knowledge and endeavor. We all and each one of us are conscientiously or unconscientiously increasing the scope of human knowledge, and the more facile we are in the task allotted to us, and in seeking for the truths with a single "I", the further shall we proceed in the direction of increasing the productivity of the individual, assuring him of a greater share in the world's goods and of leisure to partake of them, while his work shall become his most enjoyable occupation.

Journal Society Chemical Industry, Nov. 30th, 1895.

A PLEA FOR THE BUSINESS TRAINING OF THE ENGINEER

R. A. ROSS, E.E., (Toronto).

The only justification in the eyes of the community for the existence of the engineer are the results which he obtains. His business is a purely utilitarian one, the object being the production of value. Value is not measured by the cost of an engineering construction, but by the results obtained therefrom when used as a tool for the extraction of dividends. The value of the engineer to the community being determined by the results obtained from his engineering, it becomes pertinent to inquire when such results are shown. These become apparent only when the work for which he was responsible has been in operation for a time and operating profits or losses can be determined.

Without drawing the lines too closely there may be conceived to be three stages in the life of an enterprise:

1. The scientific—when the tool is forged by the engineer.
2. The business—when methods of using the tool are evolved and used.
3. The economic—when the results of the tool and its handling become apparent.

The engineer as a purely technical man will consider his work done at the end of the first stage, leaving to other hands the completion of the task and the obtaining of results therefrom. This tendency is fathered by the purely technical nature of the training which he has received, fostered by a lack of business knowledge in which he finds himself deficient and ingrained in his system by the attitude of the business world towards him, which believes the engineer to be lacking in business ability whereas it is only lack of training and confidence.

The general result so far as the engineer is concerned is that by keeping his nose so closely to the technical grindstone he has little opportunity, or even desire, to look up and see what the larger business world is doing with his product; he therefore does not take his real position in the scheme of things and attract that attention to himself and his profession which he should, nor does he do that full justice to the community which has educated him, and which has a right to demand the highest dividend possible on capital invested in his training.

No remark is more frequently heard, especially among financial and business men, than that the engineer does not understand business. And this is in general true. He is therefore hired by a company, and regarded by it merely as a species of glorified plumber. He constructs the tool with which the

---

*Mr. Ross is of the firm of Ross and Holgate, Consulting Engineers, Montreal, and has recently been engaged to deliver a course of lectures on the Business of Engineering, at McGill University.

financial man works and without which he could have no standing in the community, and being given this tool he is able to bring business methods to bear and produce results, for which he and not the engineer is given credit and reward.

The engineer is a man with a trained mind, trained to logical reasoning and deduction, brought up on good, old Euclid, thoroughly grounded in rigid scientific principles and taught to think straight. If, therefore, he applies his logically trained mind to business and economic matters with one-half the diligence which he exercises in his purely engineering functions, it is difficult to see why he should not obtain better results than the business man who generally has had no real training in business, but has absorbed such knowledge as he possesses from the business atmosphere surrounding him—does not read, study, or examine into the real reasons of things, and knows only business usage and custom. If this be doubted, inquire from business friends as to the amount of reading and real study they have given to business matters, it will be found to be inconsiderable. As a matter of fact, the engineer side-steps a business proposition whenever he can, stating in effect, if not in words, that his business is engineering and leaves the business of what should be his work to others, when given a certain amount of study and courage he could settle these questions satisfactory for himself and to the benefit of the public. The reason for this attitude on his part toward the field which promises him an improved status as a citizen, a broader knowledge of the world at large, and increased dividends, is to be found in the fact that the business part of his training is not taken up or even hinted at during his college course.

It is, of course, impossible that an art such as business is can be taught in a college devoted to science, but neither can the art of engineering be taught there. Whether there is a science of business is very questionable. There is certainly nothing in the nature of an exact science, nor even of an approximate science, but there are certain laws and general principles which if absorbed by the student during his college course would give him a different outlook and broaden his horizon. He would at least learn that there is nothing weird and incomprehensible in ordinary business terms or business methods and therefore be encouraged to extend his field of operation beyond the technical so as to embrace the business and economic end of the subject.

If, however, through lack of ability or aptitude in business matters, or through the bent of his mind being purely scientific, he does not find an opportunity to expand in the direction indicated, yet he will at least be able to understand the terms used, and to talk intelligently to men in the business world.

This expansion of the Engineer's sphere of usefulness is evidenced in the career of certain engineers in other countries who, beginning as purely technical men, have since launched out into contracting, and finally added financing and operating, so that they in their business have forged the tools, have used them and have obtained results, and the credit and returns are all theirs.

The rapid expansion of industrialism is making its demands for trained men felt more and more, and engineers are being chosen for administrative offices in large corporations and as the directing forces in large enterprises, and this tendency must of necessity increase, and who are better fitted to operate under directions of the laws of men and with a knowledge thereof than those who have built well under the much more rigid and exacting laws of nature.

In any system of engineering training, science must of necessity be the foundation, but upon this foundation the engineer may erect a superstructure which will be visible to the public, and attract attention to the fact that he is a power in the community. This superstructure, which may readily be a part of engineering, is dedicated to the business and financial departments of his business; without the foundation the structure is useless, but the foundation itself not being visible receives precious little attention from the community when the building is complete. The basement rentals are also low.

The institutions wherein engineers are taught must in justice to the profession keep pace with this tendency, and that they are beginning to do so is evidenced by the fact that a number of colleges in other countries have added to their purely technical studies a course on the business and economic aspects of engineering. In this country, McGill is about to set the example, and it would appear that the other technical schools will have to follow suit or their graduates will be distanced in the race for preferment.

There are two arguments against adding a course of this kind to the curriculum of a science school—

1. That the students are already overburdened with work.
2. The reluctance of the authorities to teach anything but science.

As regards the first, it seems to be a question as to whether certain of the more purely scientific studies could not if necessary be dropped in favor of the more practical course here-advocated, but it is thought that this may not be necessary as a fairly extensive course can be given, covering only the principles of business, without overburdening the student, for the reason that his training having been along rather strenuous lines, demanding a high degree of concentration, the study of the mechanism of business will be found to be child's play by comparison.

The second objection can be met by asking whether the college is not for the inculcation of principles. If this is true as regards science, why not as regards the business of engineering.

The engineer as he develops and gets away from purely technical routine work is supposed to be able to draw up specifications, make contracts, hire and direct labor, and report on properties. These are within his legitimate field as at present understood, and yet all of these demand that he should have in reason a knowledge of money and values, of business methods and some knowledge of law, and that he should be able to present his reports in such a way as to be readily understood by business interests.

The mere expansion of these functions with the same knowledge of principles brings him to a point where he should be able to present a financial scheme for the consideration of financial people, and practically to act as their engineer, promoter and director of the scheme at its inception and thereafter. He should be able to operate it to a successful issue, to obtain commercial results and dividends. To this end, in addition to the knowledge of business which the engineer should have to enable him to draw up specifications, contracts, etc., he should have a knowledge of the general business methods of the community in which he lives. He should understand something of stocks, bonds, bills of exchange, notes, the formation of companies, of partnerships, the general laws relating thereto, the functions and powers of different corporation officials, and the method of incorporating companies. These are matters, the principles of which an engineer trained to study can acquire. To practice is of course a different matter, and results will depend upon his ability in dealing with the world as a business proposition.

His scientific training has taught him to deal with the laws of nature. His business training should teach him how to deal with men and money and the laws relating thereto. Business has not been taught or developed as a science, and it is therefore considered an art, and ability therein can only be developed by practice. But this is so even in engineering, the science of which is taught in the colleges and the art developed later in the larger world of practice.

It is not expected, nor is it desirable that the engineer should by thus expanding his functions, eliminate the lawyer or financier. But his knowledge of business should on the other hand indicate the necessity for these gentlemen's services, and above all show just when and where their services are needed and enable him to appreciate them at their proper value when given.

In short a business training should develop a new view of his relations to other professional men and place him in the position of engaging their services rather than acting as their servant.

The engineer is a utilitarian to a commanding degree and much more so than the other professional men, such as the doctor, lawyer and clergyman. The lawyer is a special pleader and does the best he can with the case given him. The doctor buries his mistakes. The clergyman deals in the future, but the engineer has to deliver the goods and the goods have to be commercial, therefore why restrict an engineer's education to purely scientific subjects, and why not expand his horizon to enable him to take the position in the community which he deserves and can command, and enable him to reap the rewards both in credit and dividends for which such training fits him.

NOTES ON BRICK AND BRICK PIERS.

P. GILLESPIE, B. A.Sc.

A close approximation to uniformity in physical properties is not usually revealed by a series of tests on bricks in which raw material and method of manufacture are known to be substantially the same. Bricks taken from the same locality in a kiln will show results in testing which differ by considerable magnitudes. If different experimenters have operated, the results will differ much more widely. With steels and irons on the other hand, much greater uniformity is found where circumctances lead us to believe uniformity exists. Results obtained from tests on samples of these materials in cases where the process is known to be constant, differ by probably ten per cent. at the outside. What is the explanation of the difference?

In the first place, this phenomenon is due to lack of uniformity in the clay product; in the second place, to the fact that the methods of conducting tests on bricks have not been standardized to the same extent as tests on steels and irons have been. An illustration will make this clear. In conducting the crushing test, some operators employ steel plates. Some crush between cushions of blotting paper while others imbed in a batter of neat cement or of plaster of Paris. Manifestly, even if the material *were* of uniform quality, comparable results would under such diverse methods of manipulation, be very difficult of attainment. To illustrate the effect of such non-uniformity of method, a series of tests reported in Tests of Metals, 1901, is valuable. Crushing tests were made on nineteen varieties of brick, each variety being tested in three different ways, viz.—with a plaster of Paris bedding, between cardboard cushions, and between pine boards. The first method in most cases gave the greatest strength and the last the least. Of course there are exceptions, but in a range covering nineteen varieties, the general conclusion will be significant.

RESUMÉ OF RESULTS.

	Mean Strength pds. per sq. in.	Relative Strength.
Tests of Whole Bricks—		
Plaster Bedding	9,060	100
Cardboard Cushions	7,380	81
Pine Cushions	5,480	60
Tests of Half Bricks—		
Plaster Bedding	5,640	100
Cardboard Cushions	4,430	79
Pine Cushions	4,540	81

Suppose, now, these details of method and other local settings are unknown. Suppose that different experimenters have obtained these results by different methods and, as is often the case, have neglected to state the *modus operandi*. How much accuracy in such an instance would the ordinary layman's opinion contain?

The reports of the Watertown arsenal, extending over a period of many years, contain a vast amount of experimental data on bricks and brick piers as well as on other materials. Conclusions, however, are rarely drawn and deductions from experiments seldom appear in these volumes. The reader is left to make his own generalizations, which task where data are insufficient is sometimes a difficult one indeed. At the outset then, one must be careful as to what conclusions can in fairness be drawn. If the data concerning the tests be meagre; if the results have been obtained by different operators; if the methods and materials have not been identical, and finally if the number of experiments be not large, generalizations must be made with the utmost caution. The purpose of this short article is to examine the records of tests on brick and brick masonry with a view to showing some of the peculiarities and limitations of the latter and the precautions which in manufacture or construction contribute to its strength.

In order first of all to get a conception of the position occupied by brick among the various materials employed in masonry construction, crushing strength alone considered, the following table has been compiled. The data have been selected from the records of experiments conducted in the Engineering Laboratory here on Canadian building materials at various times during the past ten or twelve years. As the method of conducting the tests has been uniform throughout, it is believed that the values given are indicative of the strength of the materials tested and enable us to place them in something approaching their true relative positions.

Concrete Blocks	400 to 1,500	lbs. per	square inch
Sand Lime Brick	1,250 to 3,600	"	"
Soft Burned Clay Brick	1,000 to 2,000	"	"
Hard Burned Clay Brick	2,000 to 5,700	"	"
Pressed Brick	3,500 to 5,400	"	"
Vitrified Paving Brick	6,000 to 13,000	"	"
Roman Stone (Artificial)	1,500 to 5,000	"	"
Credit Brown Sand Stone	10,000 to 15,000	"	"
Granite, New Brunswick	15,000 to 16,000	"	"
Longford Limestone	19,400 to 22,300	"	"

POROSITY AND STRENGTH.

In the Report of Tests of Material collected at the Louisiana Purchase Exposition, St. Louis, Mo., 1904, may be found the record of upwards of 400 compression tests conducted on many different varieties of brick representing all sections of the United States. On some 113 of these, absorption tests were also made, and these too are reported. The times of immersion averaged 15 days. A study of the relation between porosity and crushing strength is interesting. That the absorption test has a value in determining the hardness or degree of burning for different deliveries of the same kind of brick is generally conceded. That it is of very much less value in comparing bricks from different localities and by different manufacturers is also pretty generally acknowledged. To some extent, the absorption is a criterion of the crushing strength. The 113 absorption tests furnished the data for a plot, the ordinates being crushing strength and the abscissae the percentage absorption. A study of this plot reveals a kind of hyperbolic relation connecting the two variables. Where the absorption is high, the strength is likely to be low. Whether it is permissible to reduce to a formula, a law with which 50% of the determinations disagree to the extent of 20% or less in either direction, may well be doubted. There is, however, a *tendency* of which this is a rough expression—

$$p\ a = 65{,}000$$

where p is crushing strength in pds. per sq. in. and a is percentage absorption.

It should be observed, too, that as different methods of conducting both the compression and absorption tests will modify results, it will be scarcely fair to apply this rule where the method of conducting either test is radically different from that adopted in the tests referred to. The following illustrations are taken at random from the Report:—

BRICK	Absorption	Strength Lbs. per sq. in.
Dark buff	6.2%	8,620
Common red	13.9	4,700
Light red, face	20.4	3,050
Dark red, paver	3.5	11,990
Light gray, sand lime	13.2	5,280

The extent of the disagreement with the formula in two selected cases is shown in the following:—

BRICK	Absorption	Strength Lbs. per sq. in.
Red, Laclede paver..........	1.0%	4,850
Dark red, vitrified...........	13.7	13,560

WEIGHT AND STRENGTH.

From the following table representing but eight tests conducted on dry-pressed and mud brick, it appears as though there is also sometimes, a relation between weight and strength.

BRICK	Weight per cubic foot	Crushing Strength lbs. per sqare in.
Dry Pressed..............	128.3	10,300
do	127.2	8,740
do	124.3	5.940
do	119.8	3,480
Mud	144.3	19,170
do	136.4	15,670
do	130.6	10,420
do	125.4	10,870

In this series, the strength is apparently nearly proportional to the excess of weight over 114 pds. per cu. ft. The relation

$$p = \frac{2000}{3} (W - 114)$$

where p is the crushing strength and W is the weight in pds. per cubic foot will be found to give values fairly close to those given in the table. It is not for a moment supposed that this relation has an extensive application. It is just possible though that for bricks from the same locality and of the same process of manufacture, some such relation might be found to exist. The numerical constants would doubtless vary quite widely in different cases, and their determination would entail the examination of many individual cases.

Mr. James Howard in the Proceedings of the American Society for Testing Materials, 1907, reports a test conducted on a vitrified shale brick manufactured by the St. Louis Vitrified and Fire Brick Company, whose crushing strength reached the phenomenal figure, 38,446 pds. per sq. in. This is the highest crushing value that has come under our notice and indicates the great possibilities for strength possessed by clay products. Howard reports also a crushing test on a brick pier of 5,608 pds. per sq. in., probably one of the greatest on record. He believes too, that the maximum of strength has not yet been reached and looks for higher results from the use of some of the stronger brick which are now on the market. That such may be possible is evidenced from the fact that the greatest strength in piers, as will be subsequently seen, has been obtained from a combination of the strongest cement jointing and the strongest brick.

MORTAR JOINTING A VARIABLE.

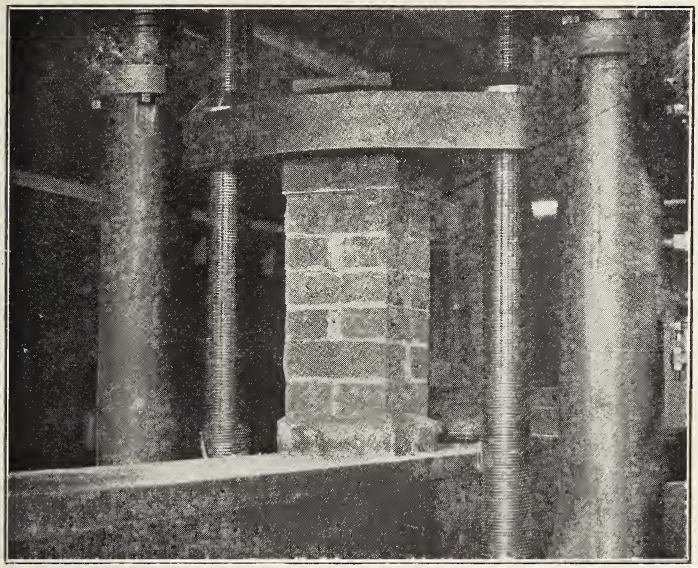
The superiority of cement mortar over lime mortar is well illustrated in the following series of tests reported by the Watertown Arsenal for 1904. In the tabulated results it will be observed that in the case of each kind of brick, supposedly the same in structure and manufacture, three kinds of jointing were employed, viz.: Neat Portland cement, a cement-sand mortar, and a lime-sand mortar. The piers were substantially alike in height and method of construction. From other data published in the same volume, the average crushing values of the bricks (plaster of Paris bedding) have been obtained and are included in the table. The relative strength of pier and brick in each case has been computed also. The piers were 12″ × 12″ × 8′ high.

Pier.	Jointing.	Age.	Strength of Pier, yards per square inch.	Strength of Brick, yards per square inch.	Strength of Pier in Terms of Strength of Brick.
Face, dry-pressed	Neat Cement	1 mo.	2,880	9,490	.30
do	1 C : 3 S	6 mo.	2,400	"	.25
do	1 L : 3 S	6 mo.	1,517	"	.16
Face, repressed	Neat Cement	6 mo.	1,925	6,780	.28
do	1 C : 3 S	6 mo.	1,670	"	.24
do	1 L : 3 S	6 mo.	1,260	"	.18
Face, wire cut...	Neat Cement	6 mo.	4,021	13,720	.29
do	1 C : 2 S	1 mo.	2,410	"	.18
do	1 L : 3 S	6 mo.	1,420	"	.10
Hard, W. Cambridge...	Neat Cement	1 mo.	4,700	10,490	.45
do	1 C : 3 S	1 mo.	1,800	"	.17
do	1 L : 3 S	6 mo.	994	"	.09
Light Hard W. Cambridge...	Neat Cement	1 mo.	1,510	7,090	.21
do	1 C : 3 S	6 mo.	1,519	"	.21
do	1 L : 3 S	6 mo.	732	"	.10
do	1 L : 3 S	5 mo.	809	"	.11
Hard, East Brookfield..	Neat Cement	6 mo.	1,969	4,840	.40
do	1 C : 3 S	6 mo.	1,800	"	.37
do	1 L : 3 S	6 mo.	733	"	.15
do	1 L : 3 S	5 mo.	866	"	.18
Light Hard, East Brookfield..	Neat Cement	6 mo.	1,061	4,470	.24
do	1 C : 3 S	6 mo.	1,224	"	.27
do	1 L : 3 S	1 mo.	465	"	.10
Hard, Mechanicsville...	Neat Cement	6 mo.	1,400	5,810	.24
do	1 C : 3 S	6 mo.	1,411	"	.24
do	1 L : 3 S	6 mo.	718	"	.12

From the above, we obtain the following averages:—
Strength of Pier in Terms of Strength of Brick.
When laid in neat cement, 30%.
" " cement mortar, 25%.
" " lime mortar, 13%.

These may be expressed in terms of the weakest as follows:
Pier having lime mortar, 100.
" " cement mortar, 192.
" " neat cement, 231.

The slight lack of uniformity as to age is not specially significant. A uniform age of six months would doubtless have made these average perecntages somewhat more divergent. It will be observed that weak bricks with a strong jointing or strong bricks with a weak jointing give strengths in piers less than when bricks and mortar are of the strongest possible kind.



Brick Pier—Before Crushing

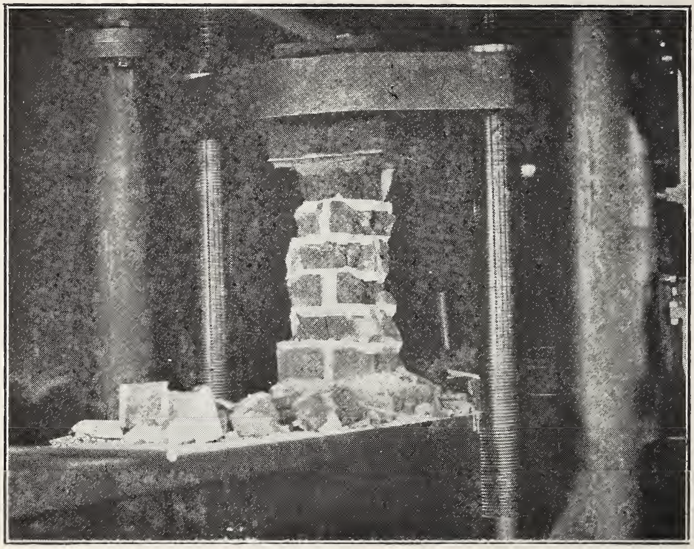
A comparison of costs for piers similarly laid is interesting. Brick work laid with ⅜" to ½" joints requires 1-3 cu. yd. of mortar per cu. yd. of masonry. If we assume lime at 30c per hundred pounds, sand at 50c per cubic yard, cement at $1.50 per barrel, and labor at current rates, we will find the prices of mortar to be substantially as follows:—

Lime one, sand three,	$1.75 per cu. yd.
Cement one, sand three,	$3.93 per cu. yd.
Neat cement..........	$11.60 per cu. yd.

If the cost of the lime-sand brickwork be assumed to be \$8.50 per cu. yd., that of cement-sand brickwork will be \$9.23, and of neat cement brickwork, \$11.78 per cubic yard. The relative costs will be:

Brickwork laid in lime mortar, 100.
" " cement mortar, 109.
" " neat cement, 139.

From this, it would appear that for the prices assumed, an increase in cost of 9 per cent. through the use of Portland cement will give an increased strength of 92 per cent, and that from an increased outlay of 39 per cent. the strength is augmented to the extent of 131 per cent. These are ample returns indeed and if strength be a desideratum, the use of Portland cement in the mortar jointing is an economical method by which to secure it. Outside of experimental laboratories neat cement mortar is almost never used. Moreover, mortars high in cement do not trowel as nicely as those containing lime. In cases where working stresses are low, and where water is not likely to be encountered, the lime mortar jointing for brick masonry will commend itself because of its cheapness.



Brick Pier—After Crushing

AGE A VARIABLE.

An examination of the results of tests with a view to discovering the effect of age on the strength of piers supposed to be of the same material and method of manufacture, shows that in most cases the strength increases with age. The exceptions to the general rule can usually be attributed to differences in material or structure that were not at first known to exist. The unwisdom of making general inferences from few examples must be guarded against. Indeed it is sometimes observed that differences in strength in a series of tests, where there is no intentional variable, is about as marked as where the age varies greatly. From Tests of Metals, 1907, the following are taken:—

Piers of Johnsonburg Pavers laid in neat cement.

Test No.	Age	Strength	Relative Strength
1760	4 days	4,218 lbs. per sq. in.	100
61	7 "	5,608 " "	133
67	1 month	4,281 " "	101
68	1 "	5,003 " "	118

Piers of Shawmut Pavers laid in neat cement.

Test No.	Age	Strength	Relative Strength
1762	4 hours	2,106 lbs. per sq. in.	100
63	2 days	3,733 " "	177
64	7 "	4,514 " "	215
80	4 months	4,089 " "	195

Piers of Wire cut Red Brick.

Test No.	Age	Mortar	Strength	Relative Strength
1820	5 months	1C : 1S	2,300 lbs. per sq in.	100
1816	24 "	1C : 2S	3,662 " "	142

In this last instance, the added strength is due doubtless to the stronger mortar as well as to the increased age. There seems to be little doubt that age will contribute strength to brick masonry. That mortar increases in strength with age is well authenticated by numerous experiments and general observation, and since the strength of brick masonry is dependent partly on the character of the jointing, this inference is quite logical. It is probable that the variation would be more marked with lime than with cement mortar.

WORKING STRESS ON BRICK MASONRY.

From the cases previously cited, the average crushing strength of matured brick piers laid in 1-3 lime mortar is about 80 tons per sq. ft., and for 1-3 cement mortar, 140 tons. A safety factor of 10 will give working stresses of 8 and 14 tons per sq. ft. respectively and these, having regard to indeterminate irregularities in both workmanship and material, do not seem too large. In many cases, the direct compressive stress on brick masonry due to its own weight only, is but a small fraction of its ultimate crushing strength. A brick wall of uniform thickness weighing 125 lbs. per cubic foot would need to have a height something in excess of 1200 feet in order to exert by its weight alone, a crushing stress of 80 tons per sq. ft. at the base. In buildings where roof and floor loads are carried to walls or piers and supported thereby, high compressive stresses may be developed in the masonry. Wind action, on walls and chimneys for example, produces additional compressive stresses on the leeward side and possibly tensile stresses on the windward. Baker cites a case of a brick chimney in Glasgow, Scotland, 468 ft. high at the bottom of which the stress due to dead load alone is 9 tons per sq. ft. It is estimated that in heavy gales this is increased on the leeward side to 15 tons per sq. foot. Roof and arch thrusts operate outward and earth pressures inward in certain cases, both giving rise to secondary stresses. These considerations will serve to show that stresses exceeding those due to direct loading only, have frequently to be provided for, and where these additional stresses cannot be computed, a wider margin of safety must be allowed. A reference to the building codes of several representative American cities shows the following to be the maximum permissible stresses for brick masonry. The stresses are given in tons per sq. ft.:

	Boston	Buffalo	New York	Chicago	St. Louis	Philadelphia	Denver	Toronto	Montreal
HARD BURNED BRICK LAID IN									
Portland Cement Mortar			15	12½	15			12	15
Cement Mortar and Lime.....	12		11½		11½	12		9	12
Lime Mortar...	8	6	8	6½	11	8	8	6	8

HEIGHT A VARIABLE.

In column formulae generally, we observe on the part of the designer, a recognition of the principle that the strength of a post reduces, other elements constant, as the slenderness increases. That the same is true of masonry columns is no doubt true, but the exact place where the effect of slenderness is likely to manifest itself in reduced strength is difficult to determine. The character of the material and workmanship and possible eccentricity in loading while in service are elements difficult of computation.

The Watertown Arsenal Report for 1886 contains a report of a series of tests on fifty-three brick piers, the chief variables being height and sectional area. An effort, somewhat successful, it is believed, was made to maintain brick, mortar and workmanship constant in quality. From these reports, two typical series have been selected, and of these, a summary is given in the tables below:

Test No.	Height.	Ultimate Strength. Pds per square inch.
851	2′	2,428
852	2′	2,117
853	4′	2,050
854	4′	1,944
855	6′	1,950
856	6′	1,750
857	8′	1,691
858	10′	1,677
859	10′	1,811

Test No.	Height.	Ultimate Strength. Pds. per square inch.
875	2′	2,327
876	2′	2,466
877	4′	1,687
878	4′	1,950
879	6′	1,700
880	6′	1,644
881	8′	1,461
882	8′	1,610
883	10′	1,347

In order to obtain if possible the law connecting strength and slenderness a plot was made on which strength and the ratio of length to diameter were the co-ordinate axes. The various tests were plotted, each test being indicated by a point. A string stretched taut was then employed to obtain the best average straight line for each series. The equations of the straight lines were then obtained and are given below.

Straight line Formulae for the Strength of Matured Brick Piers laid in 1 C: 2 S Mortar:

Eight inch piers, face brick:

$$p = 2400 - 50 \frac{L}{D}$$

Twelve inch piers, common brick:

$$p = 2100 - 75 \frac{L}{D}$$

where p = ultimate crushing strength, pds. per sq. in.
L = length and
D = diameter.

The agreement between the actual values obtained by test and those given by the equations is rather striking. The following table gives the comparison for the first of the two series. It will be observed that the average error is approximately 5%:

FACE BRICK PIERS.

Comparison between Strength as determined by Actual Test, and Strength as computed by Formulae.

Cross Section, 8″ × 8″; mortar, 1C: 2S; age, 21 mos.

Height	Actual Strength. Pds. per square inch.	Computed Strength Pds. per square inch.	Error.
2′	2,428	2,250	−7 %
2′	2,117	2,250	+6 %
4′	2,050	2,100	+2 %
4′	1,944	2,100	+7 %
6′	1,950	1,950	0 %
6′	1,750	1,950	+10 %
8′	1,691	1,800	+6 %
10′	1,677	1,650	—2 %
10′	1,811	1,650	—9 %

An examination of the results for the entire series of fifty-three piers shows that the strength varies with the cross-section as well as with the height, from which it would seem that the ultimate resistance depends in some way upon the volume.

The following straight line formulae by Kidder for the working stresses on brick piers evolved "from numerous tests and from some formulas published by Professor Ira O. Baker and from personal observation" are the results of an effort to recognize the column principle. Kidder suggests that they be applied in cases where the length exceeds six times the least diameter.

Safe loads in pds. per sq. in.

Piers laid in rich lime mortar,

$$p = 110 - 5 \frac{L}{D}$$

Piers laid in 1 to 2 natural cement mortar,

$$p = 140 - 5\tfrac{1}{2} \frac{L}{D}$$

Piers laid in 1 to 3 Portland cement mortar,

$$p = 200 - 6 \frac{L}{D}$$

For a pier 10 ft. high and 1 ft. square, the safe loads in accordance with these formulae would be:

4.3 tons if laid in lime mortar,
6.1 tons if laid in natural cement mortar
and 10.0 tons if laid in Portland cement mortar.

SUMMARY.

1. Bricks of the same material and process of manufacture exhibit considerable variation in physical properties.
2. Results of tests by different experimenters are frequently not comparable owing to difference of method.
3. Where the absorption in bricks is low, the strength is likely to be high, and *vice versa.*
4. The crushing strength is dependent to some extent on the specific gravity of the brick.
5. The strongest piers are those made from the strongest brick in conjunction with the strongest jointing.
6. The use of cement mortar is an economical method of giving increased strength to brick work.
7. The strength of brick masonry improves somewhat with age.
8. The strength of brick piers is a function of their slenderness.

The following is a reprint of an article published in the Transactions of the Engineering Society in 1896, together with some additional matter. The original paper was prepared by Mr. Jos. Keele, B. A. Sc., as a result of experiments conducted in '95-'96 by himself and Professor C. H. C Wright in the Engineering Laboratory of the School of Practical Science. Subsequent experiments, performed from time to time up to the present, have furnished the additional matter, in the collection of which, the assistance of Mr. W. G. Swan, Demonstrator in Strength of Materials, is gratefully acknowledged.

BRICKWORK MASONRY.

Results of Tests made in the Laboratory of the School of Practical Science, Toronto, during the session of 1895-6, by Messrs. Wright and Keele.

JOS. KEELE, B.A.Sc.

BRICKWORK PIERS.

The following tests were made with the object of determining the resistance to crushing offered by piers of ordinary brick, constructed in the same manner and of such materials as those most commonly used in practice in Toronto. These materials will fairly represent those in use throughout the Province of Ontario.

For this purpose a bricklayer and his assistant were engaged to procure from four different brickyards a quantity of each of their grades of bricks, the bricks being taken from the kiln as they came to hand.

The different bricks used were Kingston Road, first, second and third quality; Humber, first and second; Yorkville, first and second; Carleton, clinker and first, and Don Valley pressed brick, buff and red.

An individual test of each class of brick was made to determine its crushing strength and absorption. The absorption test was made as follows: The dry brick was carefully weighed, then immersed in water, and at the end of twenty minutes the brick was taken out, the surface water dried off, and again weighed. The brick was again immersed until the total time of immersion was thirty minutes, and again weighed.

This was the longest time allowed in water, it having been found in former tests of the same nature that the absorption of water by the brick is practically complete in thirty minutes.

The table of absorption is given below:

Kind of Brick	Weight Dry		Weight after 20 min. in water		Weight after 30 min. in water		Absorption in ounces	Absorption in p.c.
	lbs.	oz.	lbs	oz.	lbs.	oz.	oz.	
Kingston Road, 1st class.....	5	5¾	6	0	6	0	10¼	11.9
" " 2nd "	5	5½	6	2¼	6	2¼	12¾	14.9
" " 3rd "	5	1¾	6	2¼	6	2¼	14¼	17.1
Carlton Clinker...............	5	0¼	5	10	5	10½	10¼	12.7
" " 1st class......	5	0½	5	13½	5	13¾	13¼	16.4
Yorkville, 1st class..........	4	10½	5	11¾	5	11¾	17	22 7
" 2nd "	4	11¾	6	0	6	0	20¼	26.7
Humber, 1st class..............	5	7½	6	2½	6	2½	11	12.6
" 2nd "	5	8	6	6¾	6	4¾	14¾	16.7
Don Valley Pressed, red......	5	13¾	6	6	6	6½	8¾	9.3
" " buff	5	0	5	15½	5	15¾	15¾	9.7

To ascertain the crushing strength of each quality of brick, two fair and sound samples were selected and bedded between thin layers of Portland cement, thus giving two parallel planes without injury of any kind to the brick.

Ultimate Crushing Strength of Common and Pressed Brick

CLASS OF BRICK	Height	Area Exposed to Crushing in inches	Area sq. ins.	Ultimate Load in pounds	Crushing Strength in lbs. per sq. in.
Kingston Road, 1st class....	2½	8¾ x 4	35	132,400	3,783
" " 2nd "	2½	9 x 4⅛	37	62,000	1,670
	2½	8⅞ x 4⅛	36.6	63,000	1,721
" " 3rd "	2⅝	9 x 4⅛	37	67,600	1,821
	2⅝	8⅞ x 4⅛	36.6	68,000	1,857
Carleton Clinker...........	2½	8⅝ x 3⅞	33 4	190,000	5,685
" " 1st class...	2½	8¾ x 4	35	112,000	3,200
Yorkville, 1st class........	2⅝	8⅝ x 4	34.5	160,000	4,637
" 2nd "	2½	8¾ x 4	35	107,000	3,057
	2½	8¾ x 4	35	112,000	3,200
Humber, 1st "	2¼	8⅞ x 4	35.5	43,400	1,222
	2½	8⅝ x 4	34.5	50,000	1,449
" 2nd "	2½	8⅞ x 4¼	36 6	72,000	1,966
	2½	8⅞ x 4¼	36.6	64,000	1,748
Don Valley, red.....	2⅜	8⅜ x 4	34 3	184,000	5,372
" " buff		8½ x 4⅛	35	125,000	3,571

The piers were built by a skilled bricklayer, who also provided the lime mortar, which consisted of 4½ yards of Bloor street coarse sand to ten barrels of lime, this being about the proportion of two parts sand to one part lime. The cement mortar was mixed in the proportion of three parts sand to one part of good Portland cement. While the piers were being built, two cubes of each class of mortar were prepared and set aside for the purpose of ascertaining their resistance to crushing, thus giving a complete record of all the materials used.

Ultimate Crushing Strength of Mortar, 2½ months old

CLASS	Height in inches	Area Exposed to Crushing in inches	Area sq. ins.	Ultimate Load in pounds	Crushing Strength in lbs. per sq. in.
Lime Mortar, 2 to 1..	5	4⅝ x 4⅞	22.5	1,200	53
" " 2 to 1..	4⅞	4⅝ x 4¾	22	1,700	78
Cement Mortar, 3 to 1	5	5 x 5	25	33,800	1,352

The piers were built and laid aside to harden in the mechanical laboratory of the School of Practical Science, in a temperature which averaged about 60° Fahrenheit, and were prepared for the test as follows: A thin mortar of neat cement was spread on a smooth cast-iron plate, and the pier placed upon the mortar and left until the cement hardened. The bottom bed was then trimmed off flush with the sides, the pier placed on the testing machine, and a layer of neat Portland cement mortar was placed on top, the pier was slid under the head of the machine, and the head was brought to its bearing while the mortar was yet soft.

This method ensured two parallel beds and gave a uniformly distributed stress on the pier. The load was applied slowly and continuously, until complete failure of the pier occurred.

Pier No. 1:

Description—Humber, 1st class, laid in lime mortar, ⅜ in. joints.

Size of pier, 9″ × 9″..........area, 81 square inches
Length, 24 courses ....73 inches
Age ....10 days
Ultimate load ....23,600 pounds
" strength per sq. inch ....291 pounds
" " " foot ....20.9 tons

This pier was built on the testing machine; with lime mortar on top and bottom bed, the head of machine was brought down to a level bearing, and pier allowed to harden in position for ten days.

The pier failed by spreading a little at the head, a wide crack running down the centre to about half the height of the pier.

Pier No. 2:

Description—Kingston Road, 1st class, laid in lime mortar with ⅜″ joints.

Size of pier, 8⅞″ × 8⅞″	area, 78.75 square inches
Length, 8 courses	23 inches
Weight	114 pounds
Age	2½ months
Ultimate load	44,000 pounds
Crushing strength per square inch	558 pounds
Crushing strength per square foot	40.2 tons

The pier sustained a high load without sign of fracture, but was completely destroyed under the ultimate load.

Pier No. 3:

Description—Kingston Road, 2nd class, laid in lime mortar with ⅜″ joints.

Size of pier 9″ × 9″	area, 81 square inches
Length, 8 courses	24 inches
Weight	114 pounds
Age	2½ months
Crushing strength per square inch Crushing strength per square foot	Not determined by experiment.

The bottom bed used in this case was the one-inch board upon which the pier was originally built; the board appeared to be slightly warped, and split under the application of the load, causing a variation in the stress, to which is due the early failure of the pier.

Pier No. 4:

Description—Kingston Road, 3rd class, laid in lime mortar with ⅜″ joints.

Size of pier 9″ × 9″	area, 81 square inches
Length, 8 courses	24 inches
Weight	110 pounds
Age	2½ months
Ultimate load	24,000 pounds
Crushing strength per square inch	296 pounds
Crushing strength per square foot	21.3 tons

Failure occurred by splitting of the bricks in the upper courses, then wide vertical cracks opened throughout the whole length, and under highest load every brick in the pier was shattered.

Pier No. 5:

Description—Humber, 1st class, laid in lime mortar.

Size of pier, 9″ × 9″	area, 81 square inches
Length, 8 courses	24 inches
Weight	122 pounds
Age	2½ months
Ultimate load	28,000 pounds
Crushing strength per square inch	346 pounds
Crushing strength per square foot	24.8 tons

The pier held well together until near the ultimate load, then long continuous cracks appeared, with final rupture of the whole pier.

Pier No. 6:

Description—Humber, 2nd class, laid in lime mortar.

Size of pier, 8¾″ × 8¾″	area, 76.5 square inches
Length, 8 courses	23½ inches
Weight	118 pounds
Age	2½ months
Ultimate load	22,400 pounds
Crushing strength per square inch	293 pounds
Crushing strength per square foot	21 tons

All the bricks in the upper portion were completely shattered, the principal failure occurring along one corner of pier.

Pier No. 7:

Description—Carleton Clinker, laid in lime mortar with ⅜″ joints.

Size of pier, 8⅝″ × 8⅜″	area, 72 square inches
Length, 8 courses	22 inches
Weight	114 pounds
Age	2½ months
Ultimate load	44,000 pounds
Crushing strength per square inch	609 pounds
Crushing strength per square foot	43.8 tons

The pier failed, with continuous lines of fracture up and down the four sides, only one brick on the lower bed being uninjured after the test.

Pier No. 8:

Description—Carleton, 1st class, laid in mortar with ⅜″ joints.

Size of pier, 8¾″ × 8¾″	area, 76.5 square inches
Length, 8 courses	23½ inches
Weight	110 pounds
Age	2½ months
Ultimate load	41,000 pounds
Crushing strength per square inch	535 pounds
Crushing strength per square foot	38.5 tons

The pier was completely shattered under the highest load. The mortar crumbled out like sand, and had very little effect in holding any portions of the pier together.

Pier No. 9:

Description—Yorkville, No. 1, white brick, laid in lime mortar with ⅜″ joints.

Size of pier, 8¾″ × 8¾″	area, 76.5 square inches
Length, 5 courses	14½ inches
Weight	65 pounds
Age	2½ months
Ultimate load	39,000 pounds

Crushing strength per square inch	509 pounds
Crushing strength per square foot	36.6 tons

Small cracks appeared as the load was put on. As the highest load was approached portions of the pier spalled off, and finally shattered to fragments under the highest load.

Pier No. 10:

Description—Yorkville white brick No. 2, with pinkish shade, laid in lime mortar with ⅜" joints.

Size of pier, 8¾" × 8¾"	area, 76.5 square inches
Length, 8 courses	23½ inches
Weight	105 pounds
Age	2½ months
Ultimate load	30,000 pounds
Crushing strength per square inch	392 pounds
Crushing strength per square foot	28.2 tons

Fine cracks appeared early in the test, which increased to long vertical cracks, running the length of the pier, portions of the brick spalled off, and under the highest load given above the pier was totally destroyed.

Pier No. 11:

Description—Don Valley pressed brick, buff color, laid in lime mortar.

Size of pier, 8⅝" × 8⅝"	area, 74.4 square inches
Length, 8 courses	21 inches
Weight	97 pounds
Age	2½ months
Ultimate load	51,000 pounds
Crushing strength per square inch	686 pounds
Crushing strength per square foot	49.4 tons

As the highest load was approached, fine cracks appeared, which were confined to individual bricks, and were not continuous down the length of the pier; the fracture was rather of a crumbling nature.

Pier No. 12:

Description—Don Valley pressed brick, red color, laid in lime mortar.

Size of pier, 8½" × 8½"	area, 72.25 square inches
Length, 8 courses	21½ inches
Weight	110 pounds
Age	2½ months
Ultimate load	88,000 pounds
Crushing strength per square inch	1,218 pounds
Crushing strength per square foot	87.7 tons

The failure of this pier was of somewhat the same nature as that of the last, but the brickwork held together better under the ultimate load.

CEMENT PIERS.

Pier No. 13:

Description—Yorkville, 1st class, white color, laid in cement mortar.

Size of pier, 8⅝″ × 8⅝″	area, 74.4 square inches
Length, 8 courses	24 inches
Weight	110 pounds
Age	2½ months
Ultimate load	79,000 pounds
Ultimate load per square inch	1,062 pounds
Ultimate load per square foot	76.5 tons

The pier held together well, and did not show much sign of failure until the highest load was reached; the pier was destroyed in the test, probably owing to the brittle nature of this brick.

Pier No. 14:

Description—Yorkville, 2nd class, color white with pink tint, laid in cement mortar.

Size of pier, 8¾″ × 8¾″	area, 76.5 square inches
Length, 8 courses	24 inches
Weight	111 pounds
Age	2½ months
Ultimate load	78,000 pounds
Ultimate strength per square inch	1,018 pounds
Ultimate strength per square foot	73.3 tons

This pier was well built, and shows the value of a cement mortar for laying brickwork, as its binding qualities allow the brick to develop nearly its full strength.

Pier No. 15:

Description—Humber, 2nd class, laid in cement mortar.

Size of pier, 9″ × 9″	area, 81 square inches
Length, 8 courses	24 inches
Weight	124 pounds
Age	2¼ months
Ultimate load	91,600 pounds
Ultimate strength per square inch	1,131 pounds
Ultimate strength per square foot	81.4 tons

Fine cracks occurred in some of the bricks only under nearly the highest load, but total destruction of the pier took place under the ultimate load, but did not shatter so badly as in the case of those laid in lime mortar.

Pier No. 16:

Description—Kingston Road, 2nd class, laid in cement mortar.

Size of pier, 9″ × 9″	area, 81 square inches
Length, 8 courses	23½ inches
Age	2½ months
Ultimate load	69,000 pounds
Ultimate strength per square inch	852 pounds
Ultimate strength per square foot	61.3 tons

This pier held together even under the ultimate load, the failure occurring through actual crushing of some of the upper bricks. After pier was removed from the machine, only small portions of it could be forced away from the mass.

Pier No. 17:

Description—Carleton Clinker, laid in cement mortar.

Size of pier, 8½″ × 8½″	area, 72.25 square inches
Length, 8 courses	22¾. inches
Weight	115 pounds
Age	2½ months
Ultimate load	174,000 pounds
Ultimate strength per square inch	2,408 pounds
Ultimate strength per square foot	173.4 tons

Fine cracks appeared toward the end of test; these cracks were not continuous down the length of pier, nor did they increase much in width under the highest load.

Pier No. 18:

While working on this pier the friction clutch of the machine gave way, and the tests were discontinued for the present.

Pier No. 1:

Description—The pier in question was tested in December, 1904. It consists of Kingston Road brick, best quality, built in 8 courses and laid in 3:1 cement mortar. The joints were ⅜″ thick.

Size, 8½″ × 8½″	area 72.25 square inches
Height	2 feet
Age	8 years (built in 1896)
Ultimate load	184,150 pounds
Crushing strength per square inch	2,550 pounds
Crushing strength per square foot	183.5 tons

Pier No. 2:

Description—This pier was tested in January, 1906. It consisted of Carlton 2nd class brick, built in 6 courses, laid in 2:1 lime mortar. The joints were ⅜″ thick.

Size, 8½″ × 8½″	area, 72.25 square inches
Height	16 inches
Age	6 years
Ultimate load	75,150 pounds
Crushing strength per square inch	1,040 pounds
Crushing strength per square foot	74.4 tons

Pier No. 3:

Description—This pier was tested in January, 1906. It consisted of Kingston Road 1st class brick, built in 5 courses in 3:1 cement mortar. Joints ⅜″.

Size, 8¾″ × 8¾″	area, 76.56 square inches
Height	14 inches
Age	1 month
Ultimate load	117,200 pounds
Crushing strength per square inch	1,530 pounds
Crushing strength per square foot	109.4 tons

Pier No. 4:

Description—The pier in question was tested in January, 1906. It consisted of Carleton brick, 2nd class, built in 6 courses and laid in 2:1 lime mortar. The joints were ⅜″ thick.

Size, 8½″ × 8½″	area 72.25 square inches
Height	1 foot, 5 inches
Age	6 years (built in 1900)
Ultimate load	75,000 pounds
Crushing strength per square inch	1,040 pounds
Crushing strength per square foot	74.9 tons

Pier No. 5:

Description—The pier in question was tested in December, 1907. It consisted of Yorkville brick, 2nd class, built in 5 courses and laid in 2:1 lime mortar. The joints were ⅜″ thick.

Size, 8¾″ × 8¾″	area, 76.56 square inches
Height	1 foot, 2½ inches
Age	2 years
Ultimate load	106,000 pounds
Crushing strength per square inch	1,382 pounds
Crushing strength per square foot	99.5 tons

Pier No. 6:

Description—This pier was tested in January, 1908. It consists of 2nd class Yorkshire brick, built in 5 courses and laid in 3:1 cement mortar. The joints were ⅜″ thick.

Size, 8¾″ × 8¾″	area, 76.56 square inches
Height	1 foot, 2½ inches
Age	2 years
Ultimate load	87,000 pounds
Crushing strength per square inch	1,140 pounds
Crushing strength per square foot	81.43 tons

Pier No. 7:

Description—The pier in question was tested in January, 1908. It consisted of 5 layers of Humber brick, 2nd class, laid in 2:1 lime mortar. The joints were ⅜″ thick.

Size, 9″ × 9″	area, 81 square inches
Height	1 foot, 2½ inches
Age	2 years, 1 month
Ultimate load	43,000 pounds
Crushing strength per square inches	531 pounds
Crushing strength per square foot	38.2 tons

Pier No. 8:

Description—This pier was tested in March, 1908. It consisted of Kingston Road 2nd class brick, built in 12 courses, laid in 2:1 lime mortar. The joints were ⅜″ thick.

Size, 8¾" × 8¾" .... area, 76.56 square inches
Height .... 2 feet, 10 inches
Age .... 12 years
Ultimate load .... 67,200 pounds
Crushing strength per square inch .... 878 pounds
Crushing strength per square foot .... 62.71 tons

Pier No. 9:

Description—This pier was tested in March, 1908. It consisted of Carlton 1st class brick, built in 6 courses, laid in 3:1 cement mortar. The joints were ⅜" thick.

Size, 8¾" × 8¾" .... area, 76.56 square inches
Height .... 1 foot, 4 inches
Age .... 2 years
Ultimate load .... 74,600 pounds
Crushing strength per square inch ...... 2,281 pounds
Crushing strength per square foot .... 163.94 tons

Pier No. 10:

Description—This pier was tested in March, 1908. It consisted of Don Buff Pressed brick, built in 4 courses, laid in 3:1 cement mortar. The joints were ⅜" thick.

Size, 8⅝" × 8⅝" .... area, 74.4 square inches
Height .... 11 inches
Age .... 2 years
Ultimate load .... 75,000 pounds
Crushing strength per square inch ...... 1,008 pounds
Crushing strength per square foot .... 72.00 tons

Pier No. 11:

Description—This pier was tested in March, 1908. It consisted of Kingston Road 2nd class brick, built in 5 courses, laid in 2:1 lime mortar. The joints were ⅜" thick.

Size, 8¾" × 8¾" .... area, 76.56 square inches
Height .... 14 inches
Age .... 2 years
Ultimate load .... 59,000 pounds
Crushing strength per square inch .... 772 pounds
Crushing strength per square foot .... 55.14 tons

INTERPOLE MOTORS*

F. R. EWART, B.A.Sc.

The use of interpoles, or auxiliary fields of any kind, is mainly to overcome commutation difficulties in machines employed under severe conditions of service. For this reason I shall first describe the process of commutation, then show the effect of induced voltages in the short-circuited coil, proceeding to show how the voltage depends on field form, and how field form is affected by armature reaction. I shall show how the effects of armature reaction may be overcome and under what circumstances an auxiliary field is necessary. And lastly I shall discuss the application of the interpole motor and its many advantages.

Figure A of Figure 1 represents diagrammatically the flow of current in an armature. The coil C carries full current in the right hand direction, and the lead L_1 carries none until the edge of the segment S_1 reaches the heel of the Brush B. As the brush passes over the segment the current is gradually diverted from C through L_1 till half of the brush rests on S_1. The current

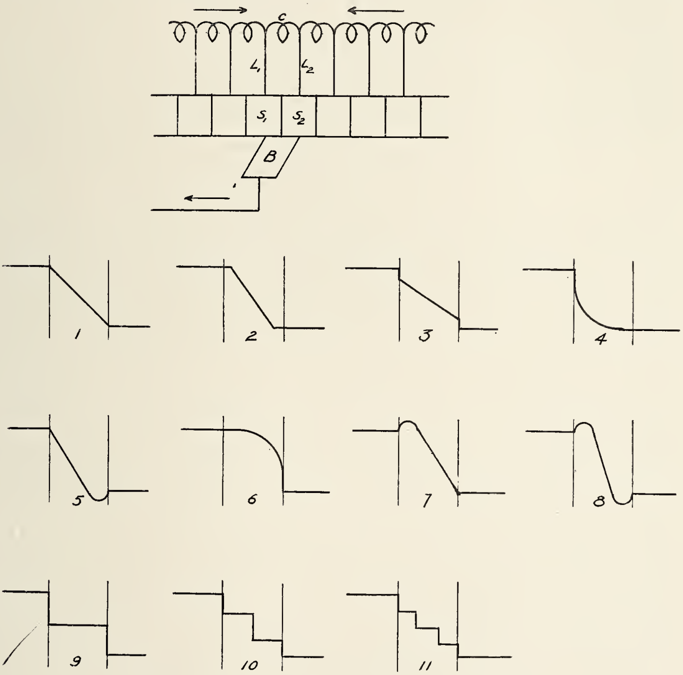


Fig. 1

Read before the S.P.S. Electrical Club Thursday, December 10th, 1908.

will then pass entirely through L_1, that is the coil is short circuited. As the brush continues its motion the current in L_2 will gradually be shifted to the coil C, until the toe of the brush leaves S_2 and the coil is carrying full current in the left hand sense. That is, the current in the coil is commutated or reversed.

This change may take place in many ways, a few of which are shown in curves 1 to 11, Figure 1. These are curves of current plotted on time interval as base, the distance between the vertical lines representing the time one commutator bar takes to pass a given point. Curve 1 shows the whole time taken in changing the current, while in curve 6 the current hangs on and reverses suddenly, i.e. very little current is diverted by the leading edge of the brush, but is impeded till it has to flow through the trailing edge. This has an effect equivalent to decreasing the width of the brush and increasing the current density. Thus the steepness of the curve indicates the current density at any point. The worst place to have high current density is at the trailing edge of the brush, as this is the point where a segment finally leaves the brush and where a spark once started will be most inclined to be drawn out and maintained. Curve 1 shows ideal commutation, giving uniform and minimum current density in the brush. This condition is most nearly realized by using brushes whose resistance is high in proportion to that of the coil, so that the ratio of currents flowing by L_1 and L_2 depends on the ratio of the surfaces of S_1 and S_2 covered by the brush. This suggests at once one good reason for the use of carbon brushes. If the resistance of the brush is low compared to that of the coil we will get commutation something like curve 9, where the coil is short circuited immediately after the edge of the brush touches its segment.

Armature coils being wound on an iron core and generally deeply imbedded in slots on it, are always highly inductive, so that it is impossible for currents in them to die down rapidly. This self-induction has the effect of producing commutation as in curve 6, causing high density at the trailing edge of the brush, a condition which we have seen to be very harmful.

If we have an active *E. M. F.* in the coil which is counter to the flow of the current and will assist in reversing it, we may get something like curve 4. Evidently the introduction of such an *E. M. F.* might be used to counteract the effect of self-induction, thus effecting a compromise between curves 4 and 6 and securing something near the straight line variation of curve 1.

If, on the other hand, the *E. M. F.* be in the same direction as the current, it will tend to maintain it, and the result may be that the current will be practically undiminished, when the segment leaves the brush and thus force the whole current to arc over from the segment to the brush after they have parted. This would mean sparking of the most vicious kind, a condition which must be remedied at all costs.

For a given speed of rotation, the *E. M. F.* in a coil at any position depends on the density of the magnetic flux at that point. A curve of flux densities on angular positions as a base,

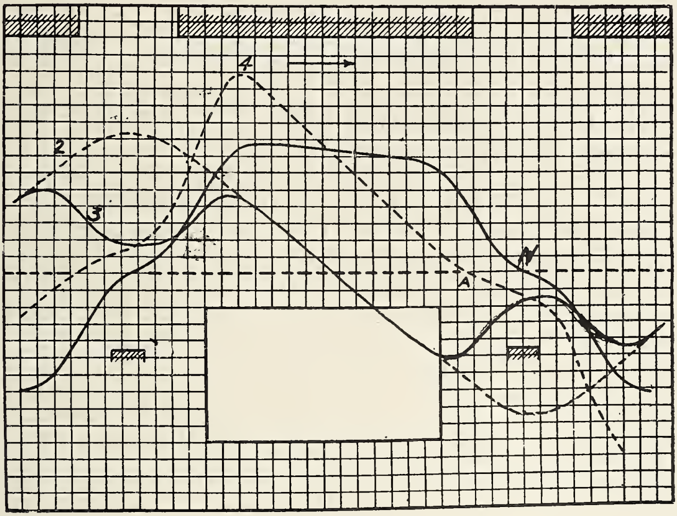


Fig. 2

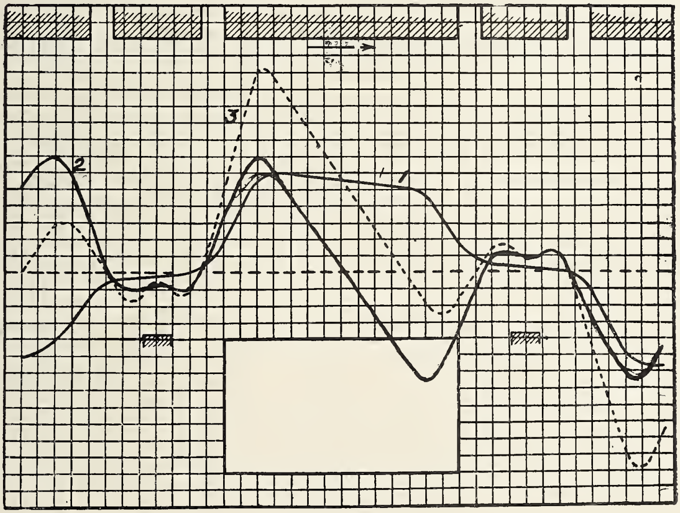


Fig. 3

is called a field form. Curve 1 Fig. 2 is an example of the field form of a shunt motor at no load. The flux is nearly uniform over the face of the pole but rapidly decreases to zero at the point N in the centre of the interpolar space. The point N is called the neutral point.

Field distribution curves may be determined in three different ways:—

(1) By exploration about the commutator with a voltmeter. This method may be used whether the machine is loaded or not, but in the former case readings in the region of commutation are unsatisfactory, since they are affected by the voltage of self-induction. Thus the main benefit from such measurements is entirely lost.

(2) By means of a fluxmeter and exploring coil. An exploring coil connected to a fluxmeter or galvanometer is inserted in different positions about the field and the kick noted when the coil is withdrawn or the field current cut off. This method can only be employed when the machine is still and can therefore only be used to give the no load curve. The method is therefore of little value in the investigation of field distortions leading to commutation troubles.

(3) The third and best method is to bring out leads to collector rings from two segments at the ends of a coil and take oscillograms of voltage. This method may be used under all conditions of speed, load, etc., and will give an absolutely faithful record of the *E. M. F.* variations in the coil. This will be the same as the field form except when the coil is commutating, where reactance voltage modifies it. But in any case the curve shows the net voltage which is employed to effect commutation, and it is this net voltage upon which commutation mainly depends.

Curve 1 (Fig. 2) is then the no load field form of a shunt motor and is the field produced by the main field alone, being only slightly distorted by the small no load current of the motor. This main field is constant for a definite shunt field excitation and is always in the same position. When the motor is loaded the armature produces a field of its own (Curve 3) which combines with the main field to produce a resultant field as shown in Curve 4.

This armature field varies in magnitude with the armature current, i.e. with the load, and its position is determined by the setting of the brushes. It is evident that an armature has a magnetization due to its own current and that the line of action of this magnetization is determined by the position of the brushes, since that is what determines the points where the current changes its sense. In fact the armature *M. M. F.* is said to be in phase with the brushes, and if commutation were taking place along the neutral axis it would be in quadrature with the *M. M. F.* of the main field. If the machine had a uniform air gap all around the armature, the maximum flux would evidently be at the brushes and zero flux at points half way between. That is we would have an armature flux as shown in Curve 2. The difference between Curves 2 and 3 is caused by the high magnetic reluctance of the circuit in the interpolar spaces.

Remembering that in the case of the motor, the flow of current is opposite to the induced *E. M. F.*, we see that we must commutate at some point a little before the point of no voltage N is reached, if we are to have a small voltage in the commutating coil acting against the current to overcome the effect of self-induction and obtain sparkless commutation. That is we must shift the brushes back a little and commutate in the "back field" or "fringe." This is in fact the method used to obtain a commutating field on any constant speed shunt motor, and is always easy of accomplishment because the main field is always stronger than the armature field and a fringe (or flux beyond the pole tip) always exists, i.e. the point of no voltage is always outside the pole tip.

But in the case of a variable speed motor, where the high speeds are attained by using a greatly reduced main field, it frequently happens that there is no fringe, i.e. the point of no voltage is under the pole tip. This is the case shown by the full load curve of Fig. 2. In this case it is impossible to get sparkless commutation by shifting the brushes backward because it is impossible for the brushes to catch up to the point A. This is because the armature flux moves with the brushes and when the brushes move under the pole tip, the arm flux at the brush is no longer that shown in Curve 3, but becomes that shown in Curve 2, so that the point A recedes before the brush and cannot be overtaken by it. It must be remembered too, that shifting the brushes backward increases the demagnetizing effect of the armature and decreases the capacity of the motor, and therefore must not be indulged in too freely.

Evidently then under extreme conditions, such as a variable speed motor, where a back field is not available for commutating purposes, a special commutating field must be provided separately. One form of auxiliary field is the winding, which was invented in 1895 by Prof. Ryan and has been called after him. It consists of a winding placed in slots on the pole face and carrying full load current. The direction of these currents is opposite to those of the armature conductors, so that the armature flux is almost exactly counterbalanced at all points. Thus the resultant full load field form differs only slightly from that at no load. This method works excellently, but has one great objection. It is very expensive. It is still used extensively on Series *A. C.* motors, where careful compensation of armature reaction is absolutely essential. But in the case of *D. C.* machines, quite as good results are accomplished much more cheaply by the use of interpoles.

These interpoles are placed in the centre of the interpolar spaces and are wound with series windings, which carry load current in such a sense that their magnetization opposes that of the armature. They are wound with sufficient turns to not only neutralize the armature flux but to produce a slight extra flux in the opposite sense, to serve as a commutating field. The field distribution curves are shown in Fig. 3. Curve 1 is for no load. Curve 2 shows flux due to armature and interpoles, and Curve 3 shows the resultant field form.

Since the interpoles are excited by the load current, their magnetization bears a constant ratio to that of the armature, and is therefore able to produce a commutating field in the right direction at all loads. It will be noticed that armature reaction is neutralized only in the region of commutation. This is just a narrow spot of unvarying width. "The question then might be asked, whether the same excitation is required on the interpoles for a given load at both high and low speeds. Experiment has proven that if the excitation of the interpoles is correct for high speeds it is also correct for all lower speeds. For although the same commutating flux is created at a given load irrespective of the speed, yet the *E. M. F.* generated in the short circuited coil is proportional to the speed. Thus a high *E. M. F.* is provided for the very quick reversal of the current at high speed and a much lower *E. M. F.* is provided for the slower reversal at low speed."

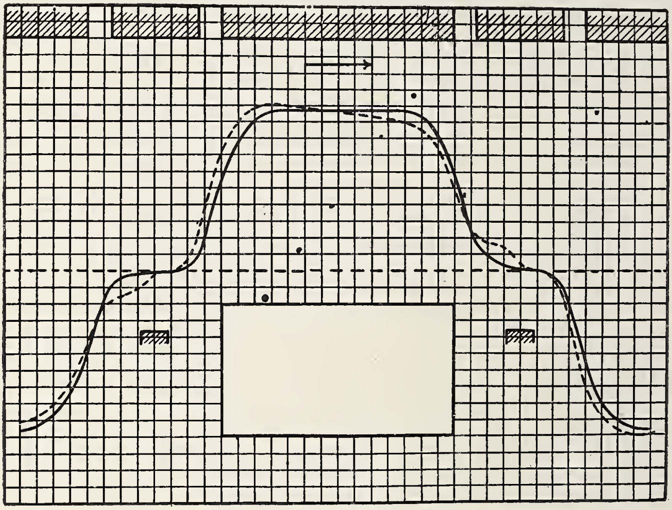


Fig. 4

Fig. 4 shows the field forms at low speed, i.e. strong main field. The curves are consequently plotted on a much smaller scale than in the other figure, so that the distortion due to armature reaction and interpoles appears relatively small.

The speed regulation of the interpole motor is about the same at all speeds. That is, the rise of speed in *R. P. M.* from full load to no load is nearly the same for all excitations. The armature $I\ R$ drop at full load is a definite fraction of the terminal voltage irrespective of the excitation and must consequently tend to cause the same percentage decrease of speed from no load to full load. This drop would be greater than in the ordinary shut motor since R includes both armature and auxiliary field winding and is consequently comparatively high. This, however, is compensated for by the fact that the auxiliary field tends to weaken the field at full load, thus causing a tendency for the speed to rise. This fact may be verified by a comparison of the curves in Figs. 2 and 3. These two effects combine to give the machine a speed regulation which is quite as good as that of the average shunt motor of the same rating.

The efficiency for any given load is practically constant. When load is constant, armature current is constant, and then torque varies directly with the armature flux, whereas speed varies inversely as the flux. Since power output varies as the product of torque and speed, it is evident that power output is independent of field flux, i.e. it is constant for a constant value of armature current or power input. Thus the efficiency is constant.

These facts are substantiated fairly well by the curves of Fig. 5, which are derived from a recent test on the interpole motor in the Electrical Laboratory. It will be noticed that the speed regulation seems to show a constant difference in R. P. M. from full load to no load instead of a constant percentage, the variation seeming to be about 60 or 70 R. P. M. for all speeds.

The greatest application of the interpole motor is for machine tool drive. In fact it was for this class of work that the interpole motor was developed, and its advantages for this and other work were brought to the notice of the engineering profession. "The requirements of a variable speed drive demand a motor, in which all the speed variation desired may be obtained in the motor itself without the necessity of either a variable voltage supply or a mechanical speed changing device." Evidently the interpole motor fits these requirements exactly. The elimination of the multi-voltage system effects a great saving in wire, and tends to simplicity in both the generation and application of power. The advantage of a uniform speed gradation, over the wide speed changes effected by any mechanical device, need scarcely be emphasized. The speed ratios employed in practice vary all the way from 2-1 to 6-1.

The motors are generally handled by controllers of the drum type, having contacts for line, armature, and starting resistance on the drum and a field rheostat at the bottom, whose arm is keyed to the main spindle and moves with it. The contacts of the drum are so arranged that the armature polarity may be reversed thus changing the sense of rotation. This also reverses the polarity of the auxiliary field, thus ensuring a commutating field that is always in the proper sense. One common form of controller has 16 forward running positions and 6 backward.

It is common practice to use resistances between points of such values, that the successive speeds are in geometric progression. Thus for 16 running speeds and a 3-1 ratio we have a step to step variation of $\sqrt[15]{3} = 7.6\%$ and for 6-1 ratio $\sqrt[15]{6} =$

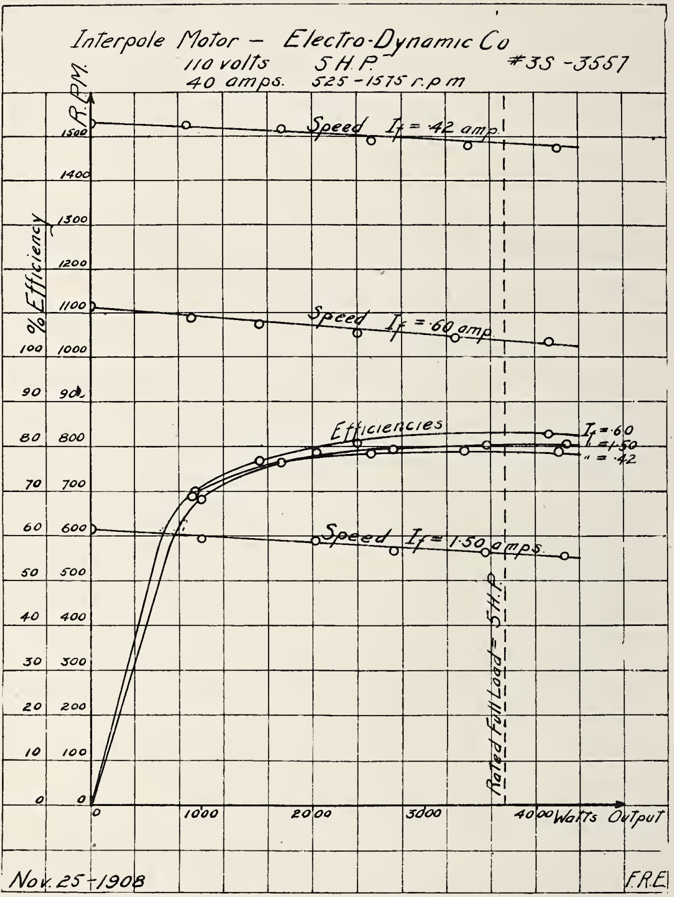


Fig. 5

12.7%. The controller may be mounted in any convenient place and position, and with long lathes is frequently mounted on the tool base so that the workman may always control the speed while standing close to his work.

Several special advantages are claimed for the use of variable speed motors in machine shop work.

(1) Elimination of line shafting.

This not only saves considerable power, but gives greater convenience and flexibility in the placing of machines.

(2) Safety and cleanliness.

Belting is always more or less dangerous and noisy and inclined to throw oil and dust.

(3) Improved and cheapened product.

Machine work is always cleaner cut when turned out at its proper speed. Then, too, the workman can push the work well up to the safe limit and loses no time in gear changing, etc. The Firth-Sterling Steel Co. found that they were able to produce 46% more work from interpole motor driven machines than from corresponding belt driven machines in the same time.

Another important use for interpoles is on railway motors. They are found to have a good effect on commutation, preventing most of the arcing and flashing which so frequently occurs when the motor is starting or is subjected to a heavy momentary overload of any kind. One great advantage of the interpole railway motor rests in the fact that the improvement in commutation permits much higher voltages to be used with safety. E. H. Anderson, designing engineer of the G. E. Co., claims that the commutation is better on an interpole motor at 1200 volts than on a corresponding type without interpoles at 600 volts. He claims that 2500 volts per motor would be quite possible; so that by using two motors in series in a car, and a double track system having the rails as a grounded neutral, 10,000 volts between trolleys might be realized. This would aid materially in the solution of the problem of long interurban lines.

Interpoles have also been frequently applied to generators on account of the advantages gained in regulation and commutation.

The interpole motor has many advantages besides improved commutation, though most of them are the direct result of this improvement.

(1) A cleaner and safer motor on account of the reduction of carbon and copper dust from brushes and commutator.

(2) Increased life of brushes and commutator.

(3) Lower core densities may be used and less iron, hence smaller iron losses; also smaller commutator losses. Thus a higher efficiency.

(4) Heating instead of commutation becomes the determining factor in the output of the machine, so that every pound of material may be worked to its greatest limit.

(5) The permissible reduction of iron raises the proportion of copper to iron, i.e. makes it "a copper machine not an iron machine." Thus a smaller and neater motor, though probably not any cheaper.

(6) Possibility of higher voltages.

(7) Greater facility in design.

(8) Possibility of increasing service capacity of motors by use of forced ventilation.

(9) Gives a perfectly reversible motor.

"It would probably be impossible to construct a commercial 5 *H.P.* shunt motor which could be suddenly reversed at full load without producing any sign of sparking, yet when commutating pole motors are subjected to such treatment the resultant sparking is not noticeable."

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 JANUARY, 1909 New Series Vol. 2, No. 3

THE YOUNG CIVIL ENGINEER.

EUGENE W. STERN.

The question which a young man keeps asking himself continually through his college days, and especially just before he graduates, is, "What shall I do next?"

It is a very important question, and one that should be carefully considered, for this is really a critical stage in his career. I shall try to help a little by drawing from my own experiences, confining my remarks to the work of the Civil Engineer, that being the profession I have followed, and I trust that this paper will be freely discussed and criticized by many of our graduates.

Although some of my remarks may apply to the work of the young mechanical and electrical engineer, my opinions in these branches of the profession would be largely that of a layman, and I will, therefore, leave this part of the field to others more familiar with it. In Mining Engineering Prof. Haultain has already covered the ground in his very interesting and valuable paper, recently published in "Applied Science."

Now what line of work or specialty is the young graduate aiming to follow later in life? Does he wish to be in professional practice as a consulting engineer, or be the engineer employed by a railroad or other corporation or contractor, or does he wish to engage in contracting or manufacturing?

This question need not be answered at once, nor can it be until he has had some years of varied practical experience and is able to judge for himself.

Now, I think it will be conceded that to be a successful engineer, or to be really successful in the broad sense in any of the higher callings, a clear knowledge of a large area of life should be acquired, because only this can give breadth and poise and ability to handle large problems and develop in one executive ability and what may be called the ethical qualities, or qualities of leadership, as distinguished from the technical.

Technical qualifications there must be, but these alone will not place one among the chosen of his profession. There must also be the ability to inspire confidence in those desiring to make use of one's services, which confidence can only be based on character, temperament, and training, and the ability to inspire employes with a love of system and order, to maintain discipline without harshness, and economy without parsimony.

There must be endurance of mind and body, and adaptability, thoroughness, efficiency, intensity, and imagination for possibilities. Having thus briefly outlined the necessary qualifications for the successful engineer as they appear to me, let us see now how the necessary preliminary training may be obtained without too much loss of time.

The young engineer, when he graduates at the University of Toronto, has a splendid technical foundation. I do not believe a better one can be obtained anywhere else. He has been thoroughly trained in the fundamental principles of his profession, and no college or university should try to do more than this. There may be post-graduate work along special lines of investigation, it is true, but the *real* post-graduate work can only be done out in the world when he commences to take a hand in the game of life.

The college cannot place responsibility on one's shoulders, whereas as soon as practical work is begun this burden immediately commences to be felt, even if the position held is a very subordinate one.

In college the young engineer has just commenced to learn engineering, having completed only the ground work of his education, and he should begin at the bottom in practical work.

Such was the advice given by Dean Galbraith twenty-four years ago to our graduating class, and my experience has been that there could have been none better.

The first years after leaving college, therefore, should be spent in obtaining experience, as broad as possible, just as the young graduate physician does in going from one hospital to another to improve himself and broaden his training.

In our profession in the early stages, the old motto about "The Rolling Stone" does not apply. While the young engineer does not gather moss he gathers what is much better, experience —experience of the world, experience of men and of things, and his corners get rounded off.

It was just for this reason that in former days the artisan, having completed his term of apprenticeship, started out as a journeyman, to improve himself by travel and variety of experience through contact with the outside world in different places before settling down to his vocation.

The young engineer, therefore, should commence at the bottom, seeking that employment which will bring him out on the work, so that he can see how engineering construction is actually carried on, and how men are handled. He should learn as early as possible to understand men, not only the man with the pick and shovel, the iron erector, or the concrete mixer, but also the man above him. This knowledge cannot be acquired too early, nor can the subject be studied too carefully. It is of much greater importance to his future advancement than technics alone.

He will soon learn some fundamental things. He will find that the day labourer is a human being, having all the human weaknesses of character which we have, perhaps more accentuated on account of his lack of education, but having at the same time a sense of right and wrong. It will be found that he can be reasoned with and under proper leadership takes pride in his work.

It will be found that the man who is able best to direct these men is not the loud-swearing boss, but the quiet-mannered man of firm character, who thoroughly knows his work, and gets it done right without much friction. He has a pleasant word for everyone who is doing his duty. And those who are not doing their duty are not on the job; but let it not be forgotten that this type of leader knows his work thoroughly. In his spare moments he is thinking out methods of how to economize in labor and how to protect his men against accidents, and also how to conserve his employer's interests; he is never found drinking with his men; they *must* respect him.

There are such men as these, born leaders, on all kinds of work—in the backwoods, on construction, and in the shop. Even if one never becomes a contractor nor employs labor, he must learn to appreciate this type of man, because some day when he is high enough up there will be such men under him, and he must know how to win their respect and confidence.

The engineer may be ever so successful as an office man, still some day he will find that his lack of knowledge of men is a very serious obstacle in his upward career, for an engineer to rise to the top must be a leader among men.

My advice, therefore, on starting out in life to the young engineer is that he should not put on any academic frills or patronizing airs. There will be very unpleasant experiences otherwise, and such deportment is a great handicap. He should be modest and thorough. If he is of the right stuff he is bound to come up, without any such useless accessories.

Now, what kind of work will enable one to gain the best experience in the shortest time, for mass of experience alone does not count unless it is broad and varied.

Railroad construction on heavy work, especially in unsettled countries or out-of-the-way places, is, I believe, the very best kind of experience to get immediately after leaving college, because one gets up against first principles, as it were, and sees how things are done from the very bottom.

The life breeds self-reliance and disposition to stand physical hardships, both of which are indispensable, and should be learned early, and the staff is thrown into more intimate relationship than in more settled communities. Besides railroad construction will enable one to see all kinds of work under way—the surveying, the clearing of the timber, earthwork, rock excavation, masonry, concrete, pile-driving, bridge building, track laying, and ballasting, and perhaps tunneling, and it will be a life out in the open air, and the further away from civilization for a time the better the experience.

It may be necessary to commence the work in the wilderness, where even food supplies at first may have to be brought in on the backs of men, exemplifying the earliest and most primitive methods of transportation; and when the work is finally completed and the welcome locomotive appears at the end of track, one engaged in such work will have seen the quick evolution in a few short months, from the most primitive to the most advanced method of transportation, made possible by the gradual progress of science throughout the many centuries, by the knowledge it has given the modern engineer to enable him to control the forces of nature for the benefit and use of mankind.

The lessons thus learned are never forgotten. Often do I find myself recalling with profit some experience gained on my railroad and survey work of many years ago. Even the hardships, the rough life, the plain food (and sometimes even the lack of this), the mosquitos and black flies and other things, are remembered with pleasure, for it was a life of strenuous work along the blazed trail, through the unknown forest and over the hills, and it was a struggle with the elemental forces of nature, and somehow most of us have enough of the primitive man in him to instinctively enjoy what our ancestors had to do.

After having two or three years' experience on railroad or other constructional work in a more or less subordinate position, it is time for a change back to the office; and I would suggest entering a bridge or structural shop, commencing in the draughting-room on shop drawings.

I have suggested a bridge and structural shop for the first experience at the shop, because the training there obtained is fundamental. All the methods are generally developed to a high dgree of refinement, and economy has been very carefully studied both in manufacture and handling of the material.

A large concern is not desirable, because the detailing work is very much sub-divided; however, a few months' experience in such a place would do no harm, if only to learn their methods; but in a smaller concern there is more chance of seeing what is being done in the shop, and very often it is possible to be sent out on the erection.

One will be able to learn the fundamentals of shop work at first hand, such as template and pattern-making, the use of the tools, the handling of the material by cranes and derricks, and the making of erection plant and rigging.

In the office the instruction is also fundamental, and the knowledge gained applies to many branches of engineering outside of buildings and bridges.

It must not be thought for one instant that a draughtsman is an engineer. An engineer must be a draughtsman, just as he must know a good deal about surveying, although a surveyor is not necessarily an engineer.

He should spend every moment of his spare time in watching the work he details go through the shop, and, if possible, should see how it is erected. In my early days I used to put in the time after draughting hours, and even at nights, when the shop was working overtime, in the shops, in order to get posted on the process of manufacturing. No reasonable employer will refuse this permission, and if such is not granted I would advise a change to some other establishment. It has been my experience that the high grade employer was very willing and anxious to have his office men take an interest in such things—he is looking for just that kind of men.

One should be punctual, and not be the last to come in and the first to quit work. He should be diligent and intense in his work, and not loaf or "soldier" like the old fellows—they remain draughtsmen all their life. He should be thorough, using great care to be exact when necessary. For instance, very often drawings may be freehand sketches if the figures are correct, and all the information given. Shop drawings, nowadays, are largely conventional. It is not really draughting in the broad sense of the word at all; therefore, do not waste time on unnecessary work, but be very careful not to omit information that the man in the shop needs. These remarks do not, of course, apply to scale drawings, which should be carefully and neatly made.

It is of great importance to know how to letter neatly and rapidly. It very often aids one to obtain the first position in the draughting-room, for very likely the first question asked the applicant is, after having stated, that he has had a technical education, is to see samples of his draughting, and if the lettering is done neatly, not only may it get him a position, but secure his advancement much more rapidly from the draughting of shop details to the making of general plans.

It is not necessary or advisable to stay for months on shop details of simple work. After the routine is acquired, one should try to get advanced to more difficult work by winning his employer's confidence in his ability to do it.

He should not get despondent if, by reason of lack of openings, he has to stay longer in a subordinate position than he feels he ought to. He will know, if he is honest with himself, when the time comes to make a change to another employer.

He should be very careful, however, not to change unless for a very good reason. "Stickativeness" at the right time is a valuable asset, but when he does leave he should try his level best to make his departure a source of regret, rather than of joy, to his former employer.

While at the bridge shop the method of organization should be thoroughly studied. It is as plendid opportunity, and should not be lost.

Carnegie was once asked to write an article on Organization. He said he would, but his price would be very high. "How high?" was asked. "Five million dollars," was his answer. The knowing *how* to create such an organization as the Carnegie Steel Co. was worth that amount to anyone who really wanted to know. He further said: "You may take all the machinery, all the plant, all the business, away from the Carnegie Steel Co., but leave me my staff and organization, and I will have it all back in five years." He has often said that his success in life has been due to his knowledge of men.

The knowing how to perfect an organization of human machinery is the most valuable knowledge one can have, and exceeds technical qualifications, but one must know the technics in general to be able to perfect an organization.

One should stay at the shop long enough, if he ultimately thinks of becoming a bridge or structural engineer, to know how to design, detail, build in the shop, and erect buildings and bridges. In my opinion, no engineer is thoroughly competent to *design* unless he knows also how to *construct* the work which he designs.

After being at this work three or four years, and having already been on construction two or three years, the young engineer will have completed the bottom course of his foundation in practical work. He will have been up against first principles, as it were, in both construction in the field and in the shop. He should now look about him, and try to see whither he should begin to steer. He will by this time be able to tell from his own experiences, whether or not he wants to remain a professional civil engineer with some specialty untimately in view or whether or not to go into some line of manufacturing work or contracting.

If at this time he has the means to travel he should spend a year abroad if he intends being a professional engineer, studying European methods and designs. This study should be abroad and far-reaching.

He need not hesitate about engaging in manufacturing or contracting work if he has the taste for it. The technical training and practical experience already obtained are a splendid foundation for this. He will be able to tell when the time comes whether or not he is fitted for this kind of work. One's temperament has a great deal to do with his success as a contractor or manufacturer.

It is of value to know something about bookkeeping and stenography might be valuable, as there are many cases where private secretaries have been able to rise to very important positions.

Another important thing is the keeping of costs of all kinds of work. My practice has been to keep these on regular card index-filing cards. The cost memos should, to be of any value, record not only the amount of the material used and the price per unit for this material, but also the number of hours and rate of wages of the different kinds of labor.

The salary which an engineer receives during his first years is of the least importance. In seeking employment it should be the value of the experience in building his foundation of knowledge which should count, unless, of course, there are special reasons why he should earn as much salary as possible.

I do not mean to say he should be satisfied with a nominal salary or less than what is the prevailing rate of compensation for the same kind of work. This he should obtain, as he would be doing both himself and his profession an injustice if he does not. What I mean to say, however, is that if two positions are offered, in one of which the salary is less than the other, but in which there is a chance of obtaining more varied practical knowledge and ultimately securing greater salary, the former should be selected instead of the latter.

Each position, no matter how subordinate, should be looked upon as a stepping-stone to something better, and every experience, even if unfortunate, be remembered, for such lessons are of great value. One actually learns more from his failures than from his successes.

I have been asked frequently by young engineers if they should accept positions in the tropics in unhealthy districts, and my advice has always been not to do so, for one should not handicap his whole future career by risking his health in his early years, and it is not at all necessary. There are plenty of positions open in Canada and the United States, and there is always a scarcity of thoroughly competent men to fill them.

As to positions in Municipal Bureaus or under the Government, I would advise against these in the earlier stages of practical work, because I think that broad and strenuous experience is better gained elsewhere. It is time enough after the foundation has been thoroughly laid to step into a position under Government, if it is desirable.

And now, just a few words more of advice to the young engineer. He should not drag out the work he has to do, in attempting a degree of refinement which it does not warrant, yet he should not get careless; when he feels that he is getting that way he should shake himself up a bit, or the boss, if he is of the right kind, will surely do so. He should apply the rule of common sense to everything he does. After having completed a design, for instance, let him forget all about the theory and mathematics involved, and try to look at it from the standpoint of practicability—the shop processes, the erection of the work in the field. Let him seek eagerly the results of practical experience, and listen with respect to advice of even the rule-of-thumb practical man who knows his work. He should not try to get another man's job. He should be loyal to the man above him. If he cannot be so on account of this man's lack of integrity, he should either ask for a change or resign. But only a peculiarity of temperament in his employer is not a sufficient excuse for a change. One *must* learn to be tactful and to get along with people both above and below him.

A tendency to change one's position too often without just cause shows a lack of steadfastness.

An employer always wants to know why one seeking employment has changed from one position to another, and the reasons given are carefully considered in the estimate he forms of the applicant's character.

I would advise in making application for positions to clearly but *briefly* state exactly what the previous positions have been, and the experience obtained, and the reasons for leaving each of these.

A copy of a testimonial from each employer should be sent with the application. A personal interview is always to be desired if possible, as it enables the employer to "size up" his man.

The young engineer should associate himself with the local engineering club if one happens to exist, and should early join the Canadian or American Society of Civil Engineers, or both, and keep fully abreast of the times in technical matters. He should mix with those in other professions and with business men, and become known in the place where he lives. Besides, he should not neglect his general education, for after leaving college he has only commenced to be educated in the broad sense. His reading should be as diversified as possible—in history, economics, and general literature, so that some day he may become a well-balanced all-around man, not only a credit to the noble profession he has chosen for his life's work and to his Alma Mater, but also to the community wherein he lives.

[This paper of Mr. Stern's cannot but be of mutual interest to the undergraduate and young civil engineer. Mr. Stern and the editor are anxious to have the article freely discussed. Applied Science will print the discussion. Mr. Stern will sum up and complete the same in the April number. Next year it is intended to take up the discussion of "The Young Electrical and Mechanical Engineer."—Editor.]

A NOTE ON THE RELATION OF THE MINING ENGINEER TO THE PUBLIC.

H. E. T. HAULTAIN.

"The learned professions" was a term of our fathers. They had the Church and Law and Medicine and to these they perhaps added as an "honourable" rather than as a learned profession that of Arms, and this covered the list of the professions as distinguished from other walks of life. We still use the term and in an unthinking way with about the same limitations. But —nowadays, is not engineering one of the professions?

What is a profession? Who defines the word? What is not a profession? In these days what is not learnéd? Many trades call for mental activity of a higher order and for more knowledge than did the professions of our grandfathers. Should we use the term or drop it? Should we modify it by the words learned or honorable or both? In contradistinction to what other terms should we use it?

I am in the dark. I grope. I would grasp that quality or that function of engineering which makes it one of the professions. But perhaps it is not a quality nor a function, nor even an essence, but rather a blending so subtle as to defy isolation or definition. My engineering spirit rebels. I not only want to isolate this something but I want to measure it and having failed my engineering spirit shies away, retires in disappointment at failure, and goes back, content, perforce, with the overalls and the rule and the things with which they fit. But we really are with the Doctors and with the Divines and with the Lawyers. But how? Are we not learned? We are honourable. Are we? Is that the essence that we must isolate and measure. Who defines honour? If it is a function how do you express it. If it is a quality how do you measure it. Is it also a complex blending?

Perhaps the term profession *should* be shied away from. Are there not other words that we shun? Honour, for example, yes! and gentleman. In all probability their undefineableness preserves their sacredness and their strength, yes, and strange as it may seem perhaps their educative value. Gentleman is often a much abused and a hateful word and so is perhaps honourableness. But still they have a great educative value and we must not lose them.

Is it not perhaps in public service and honourableness that are to be found the main characteristics uniting the professions? Learnedness counts for little in these days where there is high mental activity in so many directions. Public service alone is not a characteristic of the professions, though Kipling tells us that Lalun's was the most ancient of professions.

But these are wanderings. I want to bring the mind of the Engineer and more particularly the Mining Engineer to the question of public service and honourableness in his profession and this can be done by the consideration of a particular phase of his work. The Consulting Mining Engineer sits in his office waiting the call of the public just as do the Doctor and the Lawyer. He has to live so he charges a fee as do the Doctor and the Lawyer. But before the fee is arranged for, and even without a fee the Doctor and the Lawyer and the Engineer are honourable men to whom personal secrets may be safely told. And the best of information and advice is at the service of the would-be client.

The client gets a disinterested opinion to the best of the ability of the Lawyer or the Doctor or the Engineer. Disinterested was the word I used. That is the quality of honourableness that we can isolate and measure. If disinterestedness is not the all of honourableness it is the main ingredient of the blend.

The professional man considers only the good of his client —if he cannot do so he does not accept the client as his. But is this all? Another client visits the Doctor and is prepared to pay a large fee and demands the best treatment at his hands, but he finds this client has smallpox and immediately his attitude towards him is somewhat changed. His first thought is not for the client but for the public. He will do the best he can for his client but subject always to the good of the public. The client cannot be allowed to travel to his friends—he cannot have the most comfortable of quarters—he cannot even have his secrecy and privacy entirely preserved. The public is the Doctor's first client, and takes right-of way. The Doctor's will in this respect is strengthened by the law of the land, but the law had its inception under the guidance of the Doctors.

The Lawyer's philosophy is not quite so fine. The Lawyer is a special pleader and will accept as a client an enemy of the public good and will protect him from the public.

Is this quite true? Nominally, No! but in reality—yes! But with this difference, the Lawyer does this only in open court where the public also has its Lawyer to defend itself and the game is played in the open. But we must remember that the Lawyer is a special pleader and presents his case from his client's point of view even to the extent of withholding truths and distorting evidence.

This is much below the standards of the Doctor and yet is compatible with honourableness for this reason and only this reason that it is done publicly and openly in the presence of an opposing counsel and a controlling, judgment giving judge.

How is it now with our Engineer and his client? A client says: I am thinking of buying B's mine. Will you examine and report on it. The Engineer does so and condemns the mine, and advises A not to purchase. B goes to the Engineer and says: I want to sell my mine to the public at a large figure. I am going to promote a company and I want an Engineer's report for the prospectus.

Now, what is this Engineer going to do? Is he a special pleader taking his client's fee and making the best of his client's case by withholding some truths and even distorting some evidence that his client may sell his mine to the public? No! most decidedly, No! Unfortunately, he cannot publicly proclaim the man as does the Doctor with his case of smallpox. All he can do is to refuse a garnished report. Now here is the danger and the trouble of it all. The man with the no-good mine goes to another man who says: I am an Engineer; I will make you out your report. This other man may have no claim whatever to be an Engineer but the public does not know this. But there are others who have been Engineers who now do this kind of thing because of greater or easier gain, but they are the prostitutes of the profession, and they should be ostracized.

The Doctors have their Medical Council—the Lawyers have their Law Society and they tell the public who are Doctors and who are Lawyers and they exercise some control over the standards of their professions. But in Canada we have no Society of Mining Engineers corresponding in any way with the Law Society and we have no publicly recognized ethics of Engineering. Is not the larger duty before the Engineer in all branches to-day the recognition of the public service and of the honourableness of his profession?

PLATE GIRDER WEB SPLICES

C. R. YOUNG, B.A.Sc.

Except in the case of plate girders of small size, it is generally impracticable, and sometimes impossible, to construct a girder without one or more web splices. The rolling mills do not manufacture plates over certain extreme lengths depending upon the width and thickness, and these limits cannot, therefore, be exceeded in design. The price per pound of the extreme sizes of plates is at the same time higher than for those of more moderate dimensions, so that the use of several plates with splices might be a cheaper arrangement than employing a single plate. It also frequently happens that the necessity for despatch in the work does not permit waiting for the delivery of full-length plates from the mills, and so the girder is made up of shorter ones which chance to be in stock at the time.

The splice provided at a given section must obviously be capable of safely resisting whatever stresses exist in the web at that section under the most unfavorable condition of loading. What this latter is must be ascertained by calculation. In the case of girders carrying moving loads it may chance that the splice will be more heavily stressed under the maximum shear at the section with the corresponding moment than under the maximum moment with the corresponding shear. This is not likely to occur, however, for splices nearer the centre of the girder than one-quarter of the span length, and, as will be shown later, the splice will generally be amply strong if designed for the maximum moment sustained by it, without regard to the effect of the corresponding shear. In keeping with the common practice of making the details of a structure such as to develop the full strength of the main material, web splices are, however, frequently designed to develop the full capacity of the net section of the web, and not merely to resist the calculated stresses that might arise at the joint.

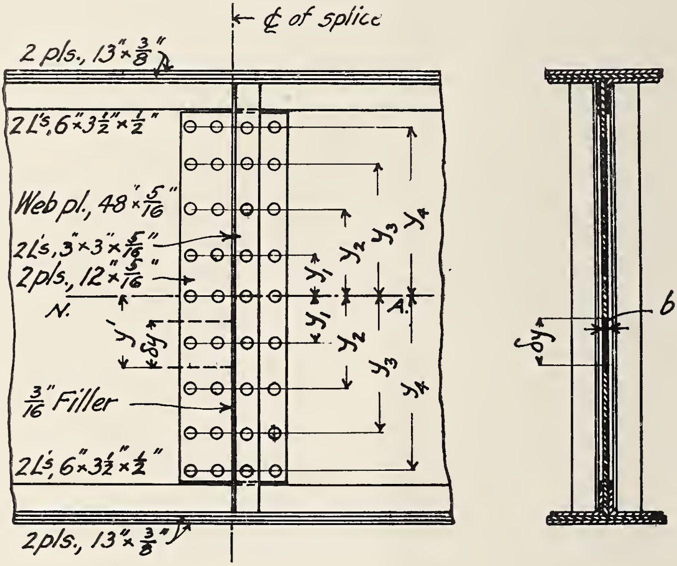


Fig. 1

When the arbitrary assumption is made, as some specifications require, that the web is not to be regarded as resisting any of the bending moment, the splice need not be proportioned to take bending stresses, but merely the shear at the section. It then consists, as shown in Figure 1, of two vertical plates, one on each side of the web, extending from the inside edges of one pair of flange angles to the inside edges of the other pair and having not less than two vertical rows of rivets on each side of the splice. The two plates are generally chosen to make up a combined thickness of one and one-half times to twice the thickness of the web. A pair of stiffener angles are commonly placed at the splice to give effective lateral support.

Although the splice is required to transmit only the vertical shear across the joint, one designed in strict conformity with this requirement would not be allowable since fewer rivets would be employed than practical considerations of rivet spacing will permit. This may be seen from a discussion of the splice illustrated in Fig. 1, which occurs at 12 feet from one end of a girder 40 feet centre to centre of bearings carrying a total static uniform load of 5000 pounds per lineal foot. The total shear at the joint is 40,000 pds. and this must be resisted by the two rows of rivets on either side of the splice. The assumption is generally made that this shear is uniformly distributed among the rivets sustaining it, which is probably not far from the truth. In addition to the direct effect of the vertical shear there is a turning moment brought to bear upon the rivets on either side of the joint equal to the vertical shear multiplied by the distance between the centres of gravity of the two groups of rivets on opposite sides of the splice. This arises from the necessarily eccentric application of the vertical shearing force. The effect is not large, however, since the splice generally constitutes a deep connection, and it is generally neglected. Using ¾-inch rivets and assuming the safe shearing and bearing stresses for rivets at 11,000 and 22,000 pds. per sq. in. respectively, the least value of one ¾-inch rivet is found to be 5160 pds., its bearing value on the 5/16-inch web plate. The number of rivets required on one side of the splice would therefore be 40,000 ÷ 5160 = 8. Since, however, the vertical rivet spacing should properly not exceed 16 times the thickness of the splice plates or 5 inches, using 5/16-inch splice plates, 18 rivets must be used on each side of the splice instead of 8. Thus it is necessary, practically, to make the splice much stronger than the requirements of stress-resistance would dictate, in this case almost enough to provide for the total end shear, or in other words, enough to develop the full capacity of the web. The total end shear being 100,000 pds., and one rivet having a value of 5160 pds., only 19 rivets would be required for this service, and therefore it is apparent that the splice might as well be at once designed to equal in strength the net section of the web plate.

If in the design of the girder the reasonable assumption is made that the web plate develops the full moment of resistance of which it is capable by virtue of its net area, the web splices must be proportioned to transmit bending, as well as shearing, stresses across the point. Assuming that the bending stress in the web increases uniformly from the neutral axis to the most remote fibre, it follows that the stresses on rivets in a web splice due to bending increase uniformly from zero at the neutral axis to a maximum at the rivet most remote from that axis. The resisting moment which a rivet will therefore exert against the bending moment will vary directly as the square of its distance from the neutral axis, since the resisting moment equals the resisting force generated by the rivet multiplied by its distance from the neutral axis. Hence it is evident that the rivets farthest away from the neutral axis are more effective in resisting bending moment than those nearer it and that those lying on the neutral axis have no value as far as resisting moment is concerned.

For this reason the type of splice shown in Fig. 1 generally proves inadequate where bending stresses have to be provided for, unless a great number of rivets are used by adopting very close vertical spacing or widening the splice plates and introducing another line of rivets on each side of the splice. Such an arrangement is highly uneconomical, for a large proportion of the rivets—those near the neutral axis—have very little value in resisting bending stresses. More efficient means have to be devised, therefore, for splicing webs in girders of the kind under discussion.

A form of splice frequently used in such cases is that shown in Fig. 2, and which has been designed for the girder of Fig. 1, the section of which is revised in conformity with the assumption that one-eighth of the gross area of the web may be considered as flange area. Instead of carrying the two vertical splice plates from flange to flange, two horizontal splice plates are placed on the web just inside the inner edges of each pair of flange angles and the vertical plates terminate at the inside edges of the horizontal plates. The latter are generally of about the same thickness as the former, that is the two plates on opposite sides of the web together make up a thickness of one and one-half times to twice the web thickness. By the employment of a splice of this type it is possible to locate a large percentage of the rivets used at a considerable distance from the neutral axis where they are highly effective in resisting bending moment. So much resisting moment is developed by the rivets in these horizontal splice plates that some designers assume that it is all generated by them and that the vertical shear is wholly resisted by the rivets in the vertical splice plates, the numbers of rivets used in these plates being arrived at on the basis of the foregoing assumptions.

While this is an ideally simple arrangement from the standpoint of the designer, it has the disadvantage of giving rise to secondary stresses of considerable magnitude in the web. The provision of a stiff, closely-riveted splice just inside each pair of flange angles has the effect of throwing most of the bending stress into the horizontal splice plates because of the principle that a load which has to travel over several paths divides itself up among these paths directly as their rigidities. This concentration of bending stress into relatively small areas of the web cross-section produces an effect of somewhat the same kind as that which would be produced if single pins were used at the ends of the horizontal splice plates and the web were not reinforced at these points. Such localizing action is evidently not to be commended.

That the concentration of large numbers of rivets at certain points in the web splice is not consistent with the assumption of uniformly-varying bending stresses on the web section may readily be shown. Referring to Fig. 1, the resisting moment of any element of the web of height δ and thickness b is equal to $\frac{f^1}{y^1} I^1$, where

f^1 = the stress in pds. per sq. in. on the extreme fibre of the element.
y^1 = the distance from the neutral axis to the extreme fibre of that element.
I^1 = moment of inertia of the cross section of the element about the neutral axis of the girder $= I + Ay^2$.
I = moment of inertia of cross-section of element about an axis through its own centre of gravity.
A = sectional area of element.
y = distance of centre of gravity of element from neutral axis of girder.

Since the moment of inertia I of the small area A about its own gravity axis is negligible compared with the term Ay^2, we may write $I^1 = Ay^2$, approximately. Now since uniform variation of stress has been assumed

$$\frac{f^1}{y^1} = \frac{f}{\frac{d}{2}}$$

where f = permissible stress at the extreme fibre of the web, which is assumed to be at the centre of gravity of the flange.
d = effective depth of girder which is assumed to be equal to the depth of the web.

The resisting moment of the element therefore equals $\frac{2\,A\,f\,y^2}{d}$

Now since the stress on rivets due to bending effect increases directly with the distance from the neutral axis, if a rivet in the gauge line of the flange angles have a safe value of r, then the greatest permissible stress on a rivet one inch from the neutral axis would be $\frac{r}{\frac{d}{2}}$, assuming that the gauge line is at the same distance from the neutral axis as the centre of gravity of the flange. A rivet at a distance y from the neutral axis would then carry a stress of $\frac{2\,r}{d} \times y$, and its resisting moment would be $\frac{2\,ry^2}{d}$

The number of rivets in the element should therefore be

$$\frac{2\,A\,f\,y^2}{d} \div \frac{2\,ry^2}{d} = \frac{A\,f}{r}.$$

This quantity is independent of the value of y, and therefore the spacing of rivets should be uniform from top to bottom of girder in order that the assumption of uniformly-varying stress may be realized. Though the concentration of rivets as far as possible from the neutral axis in a splice of the type shown in Fig. 2 is economical in the matter of riveting, this saving is effected at the expense of preventing the web at the splice from acting in the same manner as elsewhere, and probably overstressing it at certain points.

This type of splice has at the same time the minor defect of not presenting a very pleasing appearance to the eye. A suggestion of "patching" is borne to one who is not oblivious of all save the requirements of strength and dimension.

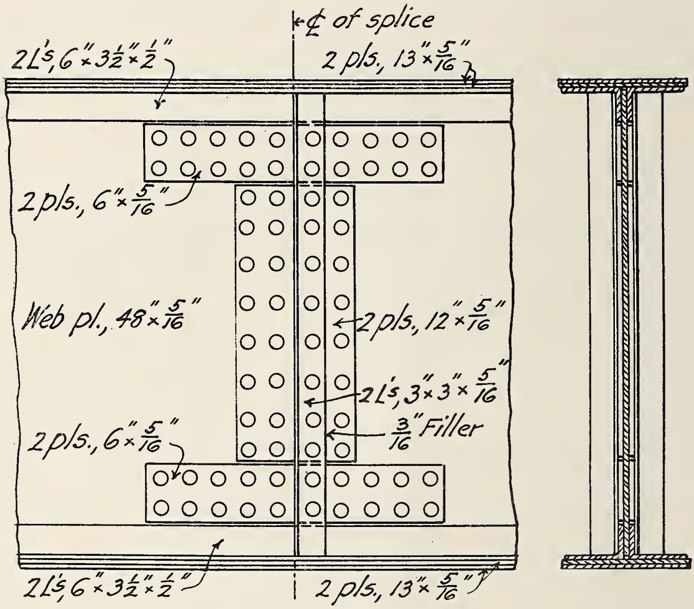


Fig. 2

A more satisfactory form of splice is that shown in Fig. 3. In this, the vertical splice plates, which are of similar thickness to those used in the types described above, run from flange to flange and horizontal splice plates are put on either side of the vertical legs of the flange angles. The rivets in the vertical splice plates are spaced about 4 inches apart vertically and as uniformly as possible, the shorter spaces, if any, being placed at the ends. Using two rows of rivets on each side of the splice in these plates is generally not sufficient to develop the full bending value of the web plate, and instead of introducing another row, the horizontal splice plates are employed. If the full value of the web were developed by the rivets in the vertical splice plates, the splice would not be well designed, for the part of the web lying between the two vertical legs of the flange angles should be spliced as well as the part covered by the vertical splice plates. Obviously the horizontal splice plates should be strong enough, and contain enough rivets, to develop the difference of resisting moment of the net section of the web and of the splice as provided by the vertical splice plates and the rivets in them. It might be urged that where more than four rivets were required in the horizontal splice plates on each side of the splice (see Fig. 3) to develop this difference of resisting moment, it is equivalent to concentrating the rivets at this point. In answer it can be said that the part of the sectional area of the horizontal splice plates and of the rivets in them which is not utilized for splicing the portion of the web between the vertical legs of the flange angles may be regarded as affording an increment in flange section in the region of the splice. Increasing the flange section at the splice makes is unnecessary to splice the web up to its full bending value and whatever resisting moment is developed by this increment of flange section need not be provided by the web splice proper.

The objection is sometimes raised against the form of splice under discussion that the horizontal splice plates necessitate additional fillers under the stiffeners which come at the splice or crimping different from that used for the other stiffener angles. These disadvantages are never serious and are preferable to the use of an arrangement by which only the part of the web between flanges is spliced either by the use of three vertical rows of rivets or two rows and horizontal splice plates on the web with the attendant concentration of rivets near the inner edges of the flange angles. Even if additional fillers have to be used under the stiffener angles at a splice of the form advocated, its superior economy of material and rivets over the splices of the two other forms mentioned above will nearly counterbalance the increase of weight necessitated by the extra fillers. Very often the crimping of the stiffeners at the web splice, if they be crimped, is, or may be made to be, the same as for the other stiffeners. This is possible when the horizontal splice plates can be made of the same thickness as the vertical splice plates, which is frequently the case.

One of the reasons given by some authorities for not using this type of splice is that the rivets in the horizontal splice plates on the vertical legs of the flange angles are put under double duty. Except in the case where the splice occurs at a point of zero shear, a certain number of rivets per lineal inch are required in the flange angles in the region of the splice for the purpose of transferring the increment of flange stress from the web to the flange angles and plates, and therefore the rivets in the horizontal splice plates are only *partially* available for the purposes of the web splice. There is no reason, however, why the rivet spacing in these plates cannot be shortened up, so as to accommodate such a number of rivets, that allowing a *part* of each rivet for purely flange riveting purposes the requirements in this respect would be fully satisfied while at the same time the remaining *parts* of rivets would fully provide for the web splice.

To illustrate the method of designing a web splice of the last type discussed, the splice shown in Fig. 3 will be investigated in detail. This joint occurs 15 feet from one end of a girder 60 feet centre to centre of bearings, carrying a total static uniform load of 6000 pds. per lineal foot. It was figured on the assumption that one-eighth of the gross area of the web acted as flange area, the permissible fibre stress in bending being taken at 16,000 pds. per sq. in. net section. The safe shearing stress on the web was taken as 10,000 pds. per sq. in., net section, the rivets being ⅞-inch in diameter and the assumed safe shearing and bearing stresses being 11,000 and 22,000 pds. per sq. in., respectively.

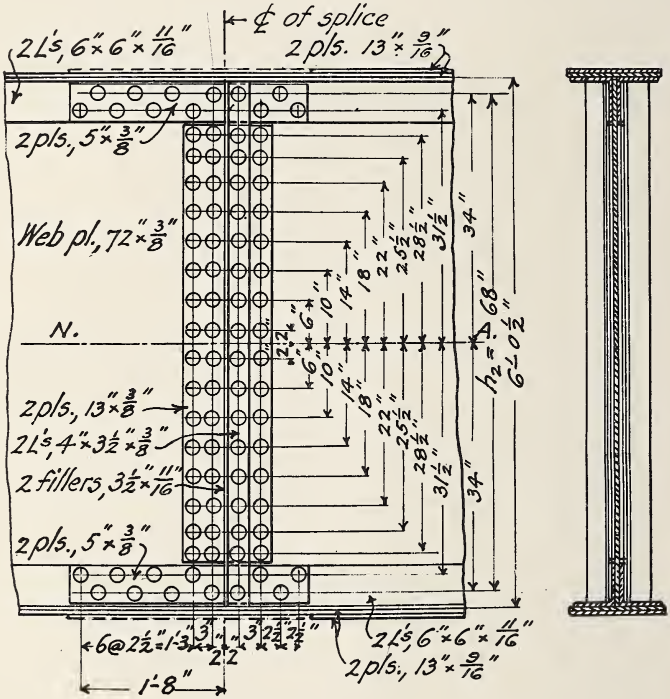


Fig. 3

Since, in general, it is not possible to locate a web splice where there is an excess of flange area, the splice will be designed to develop the full bending value of the web. In the present instance it would be permissible to splice the web for only a part of its bending value if the outer cover plates which theoretically terminate about a foot to the right of the joint were carried past that point, as shown dotted in the figure. By this device no excess material is utilized, however, but the flange is reinforced to relieve the web of part of the bending stress. The same results are attainable in a preferable way, by reinforcing the vertical legs of the flange angles. In the problem under discussion the full resisting moment of the web is equal to one-eighth its gross area multiplied by the permissible fibre stress and by the effective depth of the girder which will be assumed as the depth of the web. This gives $\frac{1}{8} \times (72 \times \frac{3}{8}) \times 16{,}000 \times 72$ 3,880,000 in.-pds.

The vertical shear at the section, which is readily found to be 90,000 pds., must also be transferred across the joint simultaneously with the bending moment. It will be shown, however, that if the splice is capable of withstanding the bending stresses it can resist the shear at the same time without revision of the design.

The most ready method of proportioning the splice is to assume the size of the two vertical splice plates and the arrangement of rivets in them, and then having calculated the resisting moment of these rivets, it becomes an easy matter to ascertain the number of rivets needed in the horizontal splice plates on the flange angles to develop the remainder of the required resisting moment. In the case at hand, the two vertical splice plates will each be assumed as $13'' \times \frac{3}{8}''$ and the vertical spacing of the rivets will be chosen as 4 inches with a few shorter spaces at the ends. The net section of the plates should in all cases be capable of developing the same resisting moment as the rivets connecting them to the web, but this will be realized for ordinary cases if the two plates have a total thickness of about twice the thickness of the web and the calculation generally need not be made.

The resisting moment of the rivets in the vertical splice plates on one side of the splice may, from what has already been said, be set down as $\frac{r}{\frac{1}{2} h_2} \Sigma \, y^2$ where

r = least value of one rivet,

h_2 = distance apart of outside gauge lines in the flange angles,

y = distance of any rivet from neutral axis.

The least value of one $\frac{7}{8}$-inch rivet will be its bearing on the $\frac{3}{8}$-inch web plate, or $\frac{7}{8} \times \frac{3}{8} \times 22{,}000 = 7{,}220$ pds., and $h_2 = 68$ inches. The resisting moment which these rivets can safely develop is therefore

$$= \frac{7220}{34} \times 4 \left\{ (2)^2 + (6)^2 + (10)^2 + \ldots . + (28.5)^2 \right\}$$

$$= 212 \div 10426 = 2{,}210{,}300 \text{ in.-pds.}$$

The difference between this and the total resisting moment of the web, or 1,677,700 in.-pds. must be made up by the rivets in the horizontal splice plates. The permissible stress on a rivet at one inch from the neutral axis due to beding being 212 pds., as determined above, the resisting moment developed by a rivet on the inner and outer gauge lines of the flange angles will be $212 \times (31.5)^2$ and 212×34^2, respectively. Assuming that m rivets are required on the inner gauge line and n on the outer one, we may then equate the resisting moment of these rivets to the balance of resisting moment left undeveloped by the rivets in the vertical splice plates, or

$$2\,m \times 212 \times (31.5)^2 + 2\,n \times 212 \times (34)^2 = 1{,}677{,}700.$$

Solving by trial it is found that m and n in whole numbers must each be equal to 2, these rivets being momentarily regarded as wholly available for the web splice.

The effect of the shear at the splice will now be investigated. Due to bending, the rivets in the outside gauge line of each pair of flange angles will be the ones most severely stressed. At the same time these rivets must resist their share of the vertical shear of 90,000 pds. which is assumed as uniformly distributed over all the rivets in the two vertical gauge lines on one side of the splice, in this case 36 rivets. The test of the sufficiency of the splice is therefore the determination whether the rivets most remote from the neutral axis are capable of withstanding the total stress, from both causes, brought to bear upon them. Since slightly less than two rivets were required in each gauge line of the horizontal splice plates for the development of resisting moment, if two are provided in each gauge line, the stress on the outer rivets need not be as much as the full value of the rivet, but the same proportion of it as the required resisting moment of the splice is to the provided resisting moment. The latter is made up of the resisting moment of the rivets in the vertical splice plates which equals 2,210,300 in.-pds. and the resisting moment of the four rivets in the horizontal splice plates which equals $4 \times 212 \times (31.5)^2 + 4 \times 212 \times (34)^2 = 1{,}821{,}700$ in.-pds. The total provided resisting moment therefore equals 4,032,000 in.-pds., assuming the extreme rivets to be stressed up to their full capacity due to bending alone, and hence the necessary stress on these rivets to develop the required resisting moment is $7220 \times \dfrac{3{,}888{,}000}{4{,}032{,}000} = 6950$ pds. Combining with this horizontal stress the vertical stress due to shear which is $90{,}000 \div 36 = 2500$ pds., we have a resultant stress of $\sqrt{(6950)^2 + (2500)^2} = 7390$ pds. on any one of the extreme rivets, or an excess of 2.4 per cent. over the permissible stress on a rivet according to the assumed rivet specification. This increase in stress is scarcely large enough to make the addition of another rivet necessary, and the case chosen is fairly representative of the most of web splices. It can generally be said, therefore, that if the splice is designed to provide for bending it will resist the corresponding shear without modification. The only case where revision might be necessary would be where the splice comes near the end of the girder, where it may have to be designed for maximum shear with the corresponding moment.

Whether the horizontal splice plates on the vertical legs of the flange angles are regarded as web splice-plates or as reinforcements of the flange, they must have sufficient net area to develop the same resisting moment as the rivets in them, it being assumed for the present that all these rivets are wholly available for the purposes of the splice. This resisting moment has been found to be 1,821,700 in.-pds., and the net area of the two plates multiplied by the permissible fibre stress in them and by the distance between a line midway between the two gauge lines in one flange to the corresponding line in the other flange should be equal or greater than this resisting moment. The permissible fibre stress in these plates will be the permissible stress at their centres or $16000 \times \frac{32.75}{36} = 14{,}550$ pds. per sq. in., and the net area of two plates will be $1{,}821{,}700 \div 14{,}550 \times 65.5 = 1.91$ sq. ins. Two 5″ × ⅜″ plates will be used giving a net area of 3.00 sq. ins.

The length of these plates must be chosen so that the rivets in them on the side of the splice nearest the support will be enough to satisfy the requirements of the web splice and at the same time transfer to the flanges the increment of flange stress which is developed between the last rivet in the plates and the centre of the joint. The result is best arrived at by trial. Assume four extra rivets in the end of these plates, the last rivet coming 20 inches from the centre of the splice. At the splice the spacing for purely flange purposes must be 5.52 ins. in the top flange and the same will be adopted for the bottom. Hence in 20 inches, $20 \div 5.52 = 3.6$ rivets are needed to transfer the increment of flange stress from the web to the flanges. The four extra rivets will be enough for this purpose and the four already provided are required for the web splice. The slight excess of 0.4 of a rivet will be required, since the rivet spacing for flange purposes near the end of the horizontal splice plates should be less than 5.52 inches.

On the other side of the splice only enough rivets are required to develop the net strength of the plates, the least value of the rivets being their double shearing value. This is the case since the most direct route for the stress in these plates to follow is from the plates directly into the flange angles and not into the web and then back into the flange angles. The net area of the two plates being 3.0 sq. ins., and the value of a ⅞-inch rivet in double shear being 13,220 pds., 3.6 rivets are required. Four rivets will be used. The increment of flange stress required to be transferred from the web to the flanges in the distance from the centre of the splice to the end rivet in these plates will not increase the number of rivets, since in considering the two effects simultaneously the least value of a rivet becomes very large—its bearing value on the two flange angles which are together 1⅜ inches thick.

INSULATION TESTING.

E. M. WOOD, B.A.Sc.

Tests on insulation are usually made for one of two purposes—to determine the insulating value of various sorts of materials, or to find out if the insulation of some particular piece of electrical apparatus is sufficient to justify its being put into use, or continued in use. Tests for the first purpose are almost exclusively confined to samples of insulation, and are made in the research or testing laboratories of manufacturing concerns. Tests of the second sort should be made on every piece of electrical apparatus before it leaves the factory, and may, with advantage, be made from time to time on the apparatus as it continues in use. It is with tests of this latter sort that this article will deal.

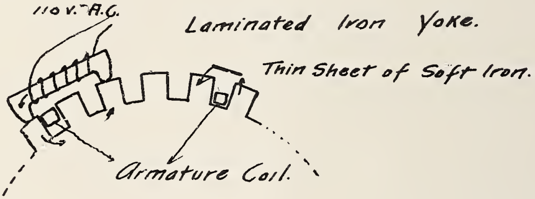


Fig. 1 — Device for locating Short Circuits in Armature Windings.

There are two classes of insulation used in electrical apparatus; first, the "minor" insulation, separating the turns and layers of the winding from each other, and, secondly, the "major" insulation, which separates the winding as a whole from other windings and from the supporting frame or case.

The insulation between turns may be tested by generating in the windings a voltage greater than their normal working voltage. This may be done in the transformer by applying twice normal voltage for one minute, or three times normal voltage for fifteen seconds to some section of the windings, thus inducing the same proportion of voltage in other windings on the same core. The applied voltage should be at as high frequency as possible to keep down "exciting" current.

For a generator, the over-voltage may be obtained by driving it above normal speed, on open circuit, with all the excitation possible. One and a half times normal voltage will be about the maximum obtainable by this method.

There are various methods of testing the wound armatures of generators and motors for short circuits between turns. One typical method is indicated in Figure I:

The portable laminated yoke shown is excited by current at 110 volts, *A. C.* The magnetic circuit is closed through the iron of the armature to be tested, so that the alternating flux surrounds one or more slots with their conductors. This sets up an *E.M.F.* in the conductors, and if there is a short circuit in the coil, heavy local currents in that coil are set up. The presence of these currents can be detected by the flux set up around the other leg of the coil in another slot, use being made of a piece of soft iron to detect the presence of this flux. In the case of a closed winding there will be current and flux anyway, but the presence of the flux is much more noticeable if there is a short circuited coil.

The most important insulation test is the test for the strength of the "major" insulation. This is practically always applied from a testing transformer. The voltage to be applied depends on the rated voltage of the piece of apparatus and the use to which it is to be put. The following table is taken from the Standardization Rules of the A. I. E. E., sections 220-226:

Rated terminal voltage of circuit.	Rated output	Testing voltage.
Up to 400 volts	Under 10 *K.W.*	1,000
" "	10 *K.W.* and over	1,500
Over 400 and less than 800	Under 10 *K.W.*	1,500
" " "	10 *K.W.* and over	2,000
Over 800 and less than 1,200	Any	3,500
Over 1,200 and less than 2,500	"	3,500
2,500 and over	"	Twice rated voltage

There are certain special exceptions noted. Transformers with primary pressures, 550-5,000 volts, whose secondaries are to be directly connected to consumption circuits should have a testing voltage of 10,000, to be applied between primary and secondary windings and between primary winding and core.

Field windings of synchronous machinery to be started by *A. C.*, with fields not excited, should be tested at 5,000 volts.

The above voltages should be applied to the machine at the temperature attained in continuous operation. However, the above voltages should be applied to new machines only, or to machines newly insulated. For old insulation the test voltage should be lower, say from 50% to 75% than given in the table, depending on the condition of the machine.

Practically all electrical apparatus exhibits under high potential test more or less electrostatic capacity. The windings and the iron act as the two plates of a condenser, with the insulation as the dielectric. This capacity requires charging current of the value, $I = C\,w\,E$ where E is the test voltage, C the capacity in farads, and w the frequency in radians per second. The capacity of the testing transformer should be such that it can supply to the test, the above current without instability of voltage ratio and without undue heating of its windings. Mr. C. E. Skinner, in an article on "Testing of Insulation," in the *Electric Journal.* Vol. II., page 538, gives the following table of suitable capacities for various kilovolt ratings:

E. M. F. Kilovolts	2	6	10	30	50	100	250.
Rating K. W.	1	3	5	30	50	100	250.

Since the tendency of an alternating voltage to break down insulation depends on its maximum instantaneous value, and since all *A.C.* voltage measuring devices indicate the square root of the mean of the squares of the instantaneous values, it is evident that for the same voltmeter indication *A.C.* waves of different shapes have different power to puncture insulation. Therefore tests, to be consistent, should be made with *A.C.* waves of standard form, namely sine wave form. The testing apparatus should be of such a nature as to produce, under conditions of test, a voltage wave form as nearly sinusoidal as possible. All tables of testing voltages, and all guarantees of insulation strength assume that the tests shall be made with *A.C.* waves of such form.

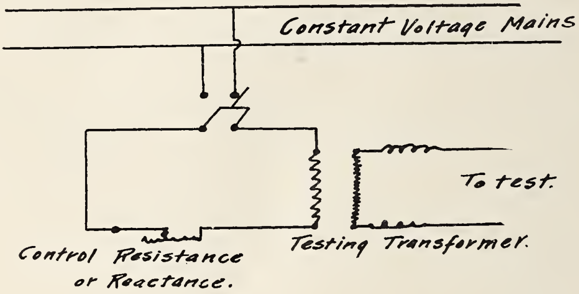


Fig 2. —Testing Set with Resistance or Reactance Control.

The severity of the test for a given voltage depends to a certain extent on the frequency, it being generally true that the higher frequencies give the more severe tests. Tests should then be made at some standard frequency, say 60 cycles, or better, at the frequency of the circuit on which the apparatus is to be used.

The test method of application of the testing voltage depends on conditions. Five of the more useful methods will be outlined.

1. By direct application from a constant potential circuit. This method may be used in all cases up to, say 2000 volts, and in case of switches, insulators, etc., which have little electrostatic capacity, for any voltages.

2. Voltage from constant potential circuit with testing transformer. Control of voltage is obtained by means of a resistance or reactance in the primary circuit as shown in Figure 2.

A water rheostat, or a variable reactance, for example a "theatre dimmer," makes a suitable form of control. The reactance has the advantage of consuming less power, and of giving steadier control, as the water resistance is liable to fluctuate, due to the formation of gas on the plates. The method is useful for voltages up to 25,000. It has the disadvantage that the controlling resistance or reactance necessarily distorts the wave form of voltage. This is not of vital importance in tests up to 25,000 volts, but eliminates the usefulness of the method for higher voltages.

3. Voltage from generator with testing transformer, control is obtained by variation of generator field. Connections are as shown in Figure 3.

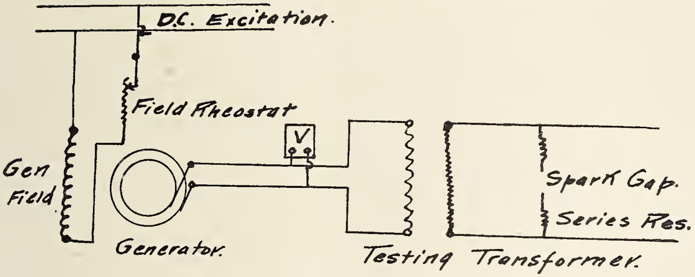


Fig. 3— Insulation Testing Set with Generator Field Control.

The method is available for any voltage and any capacity. It has the disadvantage that it requires a special generator as part of the testing set. The method gives best results when the generator is worked at approximately normal voltage, practical limits of allowable variation being from 50% to 125% normal voltage. If these limits are exceeded the wave form is liable to be distorted by the load, and especially at low excitations the voltage will be unsteady if the transformer is loaded with "leading" current, as is the case in tests on high tension power transformers, cables and all apparatus with high electrostatic capacity between windings and frame. This method or the previous one is highly satisfactory for all high potential tests on other classes of electrical machinery. For testing apparatus like high voltage transformers and cables, one of the following methods is preferable.

4. From a constant potential circuit with a testing transformer, with voltage control by auxiliary transformers whose sections are cut in or out by dial switches. Various forms are in use, one of the best of which is shown diagrammatically in Figure 4.

This uses two regulating transformers besides the testing transformer. The voltage variation is in steps of one-quarter of one per cent. from zero voltage to full rated voltage, each of the regulating transformers being in 20 sections. The variation from step to step is made without opening the primary circuit, a very important advantage, especially in tests at high voltages. In case of break down the circuit breaker C.B., opens and allows the current to pass through the choke coil, permitting the fault to be burned out if desirable.

The voltage supply is usually from some generator which gives a proper wave form. This generator may supply power for more than one testing set if required. It may be convenient to make the testing set portable, and to bring out terminals from the supply generator at proper places throughout the factory, so that the set can be rapidly connected to any set of terminals.

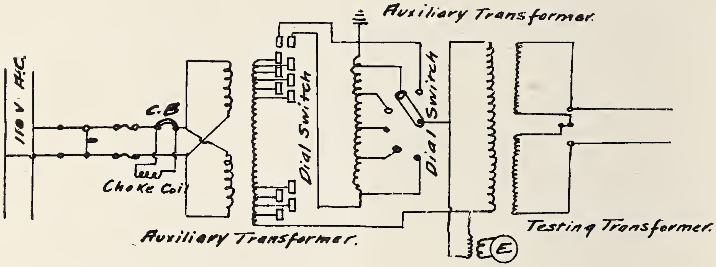


Fig. 4 — Testing Set with control by Auxiliary Transformers.

The above method is a perfectly satisfactory one for all conditions of high voltage testing.

5. Voltage from constant potential circuit with transformer, controlled by means of a single phase induction potential regulator in its primary circuit, as shown in Figure 5.

The regulator must be of special design, with the same voltage in secondary as in primary, or in other words, with a "buck" or "boost" of 100% of the line voltage. Then when working on 500 volt circuit, with primary in maximum lowering position, the voltage at the transformer primary terminals will be 500—500=0 volts. The voltage can be raised gradually, by turning the hand wheel, until the primary is in maximum "boost" position when the voltage at the primary of the testing transformer is 500 + 500 = 1000 volts. The worm-gear and wheel should be cut with a compound thread so as to give a very gradual variation of voltage. The regulator should work “snugly,” so that there is no “play” in the movable parts, but should not be so tight that it cannot be turned steadily by hand.

This method is quite satisfactory for all kinds of insulation testing. It has one advantage in that the experienced operator can judge by the way in which the “wheel” turns, approximately what is happening in the apparatus under test.

It is, of course, of great importance to be able to measure with some degree of accuracy, the voltage applied in the test. There are at present no entirely satisfactory methods, though there are several in use.

1. By ratio of transformation, with voltmeter on low tension side of testing transformer. This method neglects “regulation” and is only useful where accuracy is not important, that is in tests up to 10,000 volts.

2. By special “voltmeter coil” of known number of turns on the core of the testing transformer. This is more accurate than the first, for it eliminates that part of the regulation due to the primary.

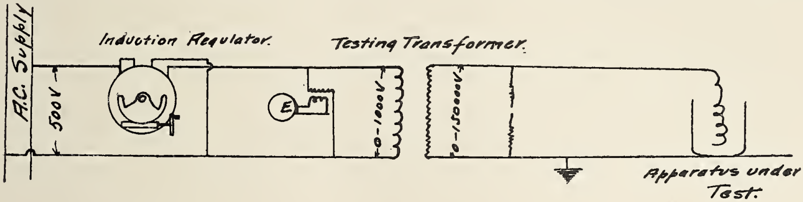


Fig. 5 - Insulation Testing Set with control by Induction Regulator.

3. By special “voltmeter coil, this being part of the high tension winding. This is theoretically an improvement on 2, but it must be taken off next to grounded terminal of the winding, and unless this is the middle of the winding these turns are liable to be not representative of the rest of the winding, on account of leakage fluxes, etc.

4. By voltmeter in the high tension circuit. This is the ideal method, but unfortunately it has serious practical limitations. The use of series resistance of potential transformer, with a voltmeter for 20,000 volts or over, would be too expensive and consume too much power for commercial use for measurement of test voltages. The static voltmeter, if there is a reliable one on the market, would be the best method available for the measurement of high voltages.

5. By spark gap in the high tension circuit. This method is the one most frequently used. It is not absolutely reliable, but with care yields fair results. The Standardization Rules of the A.I.E.E. state with regard to the use of the spark gap (Sec-

tion 245): "The spark points should consist of new sewing needles supported axically at the ends of lineas conductors, which are each at least twice the length of the gap. There should be no extraneous body near the gap within a radius of twice its length."

To prevent a large rush of current and consequently high voltage surges when the gap breaks, there should be inserted in series with each of its terminals, a resistance of one-half ohm per volt. These resistances may be carbon resistance rods, similar to those used in lightning arresters. These resistances usually decrease the gap setting for a given voltage by an amount which should be determined experimentally (about 5%).

Moderately low voltage tests, say up to 30,000 volts, require no particular care in application, except that they should be isolated so that no one will get hurt, and that the application of voltage should be fairly smooth. Voltages over 10,000 should be checked by spark gap in high tension circuit.

Voltages, 30,000 to 80,000, require more care in applying the voltage smoothly and removing it smoothly, that is, without sudden vibrations. The spark gap should be set for the required testing voltage, with the apparatus to be tested connected in as shown in Figure 5, and the voltage raised until the gap arcs over. Just *before* the break, a voltmeter reading should be taken. As soon as the gap breaks, the voltage should be lowered to zero and the gap opened say 10 % beyond the setting for the required voltage. Then voltage should be applied again with the same voltmeter reading, and held one minute, then lowered to zero. A break is indicated by the drop of the voltmeter needle to zero, and by the action of the apparatus, as burning usually follows a break-down.

At voltages higher than 80,000, with apparatus of high electrostatic capacity, it is dangerous to break the gap at full test voltage, for the arcing gap sets up voltage surges of the worst sort. The difficulty may be obviated as follows: The gap may be set at two-thirds the required voltage, and broken, with the transformer in circuit, the primary voltage being read just before the break. The voltage should be reduced to zero, and the gap opened to 10% above the distance for required testing voltage. The voltage should be then applied till the voltmeter reading is three-halves its former value, held for one minute and lowered gradually to zero. This method is sometimes satisfactory and sometimes not satisfactory. Variations are suggested by experience to fit the various conditions that arise with the different sorts of apparatus that are to be tested.

There is another insulation test, the measurement of "Insulation Resistance." This may be done roughly by a well-known high resistance voltmeter method, or by direct reading megohmmeter. It is chiefly of value in determining the state of the insulation with regard to moisture, since the greater the degree of moisture, the lower the insulation resistance. Any piece of apparatus that shows low insulation resistance (below one megohm) should be carefully dried out before an application of high potential is made.

This article will conclude with a few general practical suggestions on making the insulation tests.

1. Since the voltages used in insulation testing are all dangerous to life, too great care cannot be taken to prevent any person coming in contact with the live circuits.

2. When a machine has more than one winding, all windings except the one under test should be carefully connected to the frame, which should preferably be grounded. This is to prevent undue electrostatic stresses being induced, tending to break down the insulation from these windings to ground.

3 If there is more than one accessible point in any winding to be tested, all accessible parts should be carefully connected together electrically. This is to insure uniform application of voltage to all parts of the winding, and is a very important point. It often makes the difference for a piece of apparatus between standing the test, and failing.

4. Application of voltage should be gradual, without sudden variations but not too slow, as the severity of the test depends on its duration. For a test of 160,000 volts to a large transformer, it would be a good rule to take one minute to raise the voltage from 0 to 160,000 volts, hold at that value for one minute, and take one minute to lower the voltage to zero. No apparent impending breakdown should induce the operator to make a sudden reduction in testing voltage, for if he does, the break will become a certainty.

5. Any means possible of reducing the static discharge in a high tension test, is of advantage for the static discharges are liable to set up surges which may cause break down of insulation.

6. All connections should be made tightly and with good contact.

SOME RECENT ADVANCES IN ELECTRO-CHEMISTRY AND ELECTRO-METALLURGY.

SAUL DUSHMAN

The application of electrical energy to the performing of a large number of reactions previously carried out by purely chemical methods, has at the present time attained to a position of great commercial importance. This has been due largely to the rapid developments that have taken place in methods of power production. So long as the cost of electric power was high, the idea of supplanting ordinary chemical or metallurgical processes by the more simple electro-chemical ones could not be entertained, and electro-chemistry remained practically a laboratory science. But it was during this period that the foundations were laid for many of the most important electro-chemical industries of the present time, and, as a result, the advent of cheaper electric power found the electro-chemist prepared to utilize the advantage which was thus held out, and during the last decade the progress in electro-chemistry has been so enormous that in very many cases the electric power plant has been installed on account of the electro-chemical consumers.

Some of the electro-chemical industries, such as the carbide, carborundum, aluminium, copper-refining and caustic soda processes, have long since passed beyond the experimental stage, and their products have become vital necessities in the industrial world. Other processes, however, have obtained a great deal of prominence in the last few years, which cannot be said to be as yet in a state of assured stability, and these, since they are probably not so familiar to many of our readers, form the subject of the present article.

It is a long step from the time of Cavendish to the present, but the relatively unimportant fact discovered about the year 1776, that an electric spark passed through a moist mixture of oxygen and nitrogen will produce nitric acid, is the basis of a large number of projects, that have recently become technically important, for the fixation of atmospheric nitrogen. As is well known, our wheat crops require for their successful growth, a certain amount of fertilizer to be supplied to the soil. Nitre, or Chili saltpeter has been the substance chiefly used for this purpose in the past; but the beds of nitre in Chili are gradually becoming exhausted, and even if the supply be available for a much longer period than Crooks averred in 1892, the world has come to realize that some other source of fertilizers must be sought for, if its food supply is to remain assured. The essential requirement of a fertilizer is that it shall contain nitrogen, in a form which can readily be absorbed by plants; this condition is fulfilled very well by nitrates. Now all around us, constituting the very atmosphere we breathe are present the essential components of nitric acid, and it is therefore not surprising that the old experiment of Cavendish has again been brought to light and the question has arisen, how the fixation of atmospheric nitrogen may be performed on a commercial scale?

Lack of space will not permit us to review the preliminary work of different experimenters in Germany and England who, during the years 1897 to 1904, sought to solve the problem. Their experiments, although they did not result successfully from a commercial point of view, led to the conclusion that the main reaction in the electric arc is the formation of nitric oxide according to the equation,

$$N_2 + O_2 \rightleftarrows 2NO,$$

the amount of NO increasing with the temperature and depending at constant temperature on the concentrations of the components, according to the Mass Law. It was also shown by Nernst* that the proportion of air converted into nitric oxide is always very small, and even at 2600° *C*, it amounts to only two per cent. by volume.

These investigations thus prepared the way for the first commercial process, that devised by Birkeland and Eyde in 1904. They use a 5,000 volt alternating current arc between water-cooled copper electrodes, and by means of a magnetic field at right angles to the latter, the arc is spread out into a disc over 2 metres in diameter, thus causing almost the whole volume of air in the furnace to be raised instantaneously to a very high temperature. Owing to the circulation of air through the furnace, the nitric oxide formed there is cooled before it has a chance to dissociate, and combines, at 600° *C*, with oxygen to form the higher oxide, NO_2. This is passed through a series of towers washed with water and gives a 50 per cent. nitric acid, which is then saturated with lime and converted into a basic nitrate useful as a fertilizer. The furnaces used by Birkeland and Eyde are each of 500 kilo-watt capacity, and while in their original plant at Notodden, Norway, only 1,500 kilo-watts were used, this has since been increased to 40,000 *KW*. The yield is 70-83 grams pure nitric acid per kilo-watt hour, which corresponds to 500-600 kilograms per *KW* year, and the inventors claim that this figure can be considerably increased.** It may, however, be stated in this connection that the main reason for the success of this process is the fact that power in Norway can be obtained at the extremely low price of approximately $5.00 per *HP* year, a figure which is probably much lower than that quoted in other countries.

Simultaneously with the Birkeland-Eyde process there has been developed another one by the Badische Anilin and Soda Fabrik. "They employ an arc in a long tube through which air is passed in a whirling motion. Since 1907 they have operated an experimental plant of 2,000 *HP*, and are now planning the erection of a large 120,000 *HP* plant."*

---

*Nerust, Zeit. f. Elektrochem. 12, 527.

**Erlwein, Elektrotech Zeit, Jan., 1907.
Edstrom, Trans. Am. Electrochem, Soc., 1904.

The problem of the fixation of atmospheric nitrogen has also been solved in a totally different manner. A few years ago the search for a commercial method of producing cyanide of potassium led Drs. Frank and Caro to the discovery that when nitrogen is passed over calcium carbide at a high temperature, such as that of the electric furnace, there is produced a compound having the formula $Ca\ CN_2$ and known as cyanamide. This substance is capable of yielding a large number of interesting derivations by treatment with suitable reagents; ** thus by melting with certain fluxes it yields potassium and sodium cyanides; by the action of steam it gives off ammonia which may be converted into ammonium sulphate, and it has also found application in the organic dye industry as well as in the tempering and hardening of steel. But its most important use has been found to be as a fertilizer. Investigations by Dr. Hall at Rothamstead have shown that as a manure it is equal to nitre or any of the artificial fertilizers. It is, morever, cheaper than the basic nitrate produced by Birkeland and Eyde. According to Dr. Frank, "to replace the present consumption of Chili nitrate by cyanamide would require something like 800,000 *HP*, and works are springing up all over the world to produce it wherever water-power is abundant and cheap."*** The original works of Frank and Caro at Piano d'Orte, in Italy, are being extended at the present time to an output of 10,000 tons and numerous plants are installed or being contemplated in various European countries as well as in America. The United States Cyanamide Company is erecting a 5,000 to 6,000 tons works, at Niagara Falls, Ontario, and will shortly build another installation in Tennessee.

While important progress has thus been made in processes for the utilization of atmospheric nitrogen, electrical methods have also been invading a field in which at first there seemed to be little probability of their gaining a foothold. But the cheap, efficient manner in which electrical energy can be applied instead of coal in many branches of the iron and steel industry has caused the new methods to become an important factor even here. During the latter part of the nineteenth century immense strides had been made in both the theory and practice of iron smelting. The conditions governing the nature of the product obtained in the blast-furnaces were investigated thoroughly; so that the iron metallurgist could produce an iron of any desired quality. Similar progress had been made in the manufacture of steel. But the scarcity of coal in many places where both ore and cheap power are available caused many persons to consider the advisability of using electricity to do the work ordinarily performed by coal. The report of the Canadian Commission has been long enough before the public for all to become fairly familiar with its contents, and a great many Canadians have come to realize the immense possibilities of electro-thermic processes in this country. However, the time seems hardly ripe for an extensive development of electrical iron smelting, and we cannot do better than quote, in this connection, the opinion of Mr. J. Harden, a noted metallurgist.* After comparing the two processes for reduction of iron ore, he concludes that "where conditions are the same in both cases, as to the class of ore, amount of labor, and class of fuel available, the electric smelting furnace requires an expenditure of $9.70 per ton of produced iron, while the blast furnace requires only $6.84 or $2.86 less per ton of iron." He then reviews the difficulties which have occurred in the various types of electric furnaces, and makes the following noteworthy remarks:—

---

*Electrochem, Ind. VI, 478, Dec., 1908.

**Erlwein, Elektrotech. Zeit, Jan., 1907; also Chem. Ind., 1907.

***Report of a lecture to the Faraday Society, Electrochem, Ind., VI, 341, Aug., 1908.

"It is certainly not our intention to stamp the electric smelting furnace as a hopeless impossibility—far from it; but it is only intended to state things as they are at the present, and keep some of those optimists a little nearer the earth who dream that the days of the good old blast furnace are doomed, and must give way to the more modern electric smelting. We certainly believe that the smelting furnace is capable of attaining perfection, like everything new, but all improvements must go steadily forward, not in leaps and bounds, as the effects of undue rashness are only leading us astray." His conclusion is that electric smelting would be justifiable only in such regions as India or Western States of U.S.A., where there is practically no coke, while there are large deposits of cheap ores and abundant water-power. The carbon required for the chemical reduction could be obtained by converting wood and forest waste (which may be had there in large quantities) into charcoal.

While the success of electric smelting is thus still a probability, the production of steel in the electric furnace has become an established process. The first steps in this direction were made by the carbide and aluminium producers at a time when an over-production of these products on the European market threatened many electro-chemical installations with absolute ruin. Naturally, the products initially turned out were more or less novelties, like the ferro-alloys. A gradual education of the steel consumers has, however, not only led to a greatly increasing demand for such special alloys, but has also encouraged the electro-chemical manufacturers to enter upon the production and refining of steel. Here the electrical processes possess undoubtedly superior advantages, both from the point of view of efficiency and of ability in controlling the quality of product; and when Mr. Chas. M. Schwab** states that in his opinion the near future will see the electric steel furnace an essential part of all existing steel plants, it is evident that the advantageous results to be obtained by using the new process have been perceived by the most important steel producers.

---

*Electrochem, Ind. VII, p. 16, Jan., 1909.

**Report of Mr. Schwab's testimony before the Ways and Means Committee in the recent tariff hearings, as given in Iron Age, 1908.

Out of the large number of new developments that have occurred in this industry within the last couple of years, two are especially worth noticing. One of these is the Lash steel process, the object of which is to make any desired steel by properly mixing ore, cast iron and carbon and then subjecting the mixture to heat. "The essential features in the process seem to be the fine state of division of the constituents of the mixture, their intimate association, and the use of iron containing metalloids in considerable quantities."*

The other great development has been the Roechling-Rodenhauser modified induction furnace. The ordinary induction furnace is in reality a transformer in which the secondary is constituted by a ring of molten metal. Owing to the high temperature of the latter, careful heat insulation has been found necessary from both the primary and magnetic iron core. The result has been a considerable magnetic stray flux and consequently a low power-factor. Attempts have been made to reduce this defect by lowering the frequency of the alternating current generators, and frequencies as low as 15 have been used. But the most recent innovation due to Messrs. H. Roechling and Rodenhauser of the Roechling iron and steel works in Voelkingen, Germany,** consists in having an additional secondary coil connected with metal plates which are separated from the molten bath by a refractory electrolytic conductor of the same kind as used in the Nernst lamp, so that the metal is heated not only by induction currents but also by currents passing through it between the electrode plates. Single-phase current was originally used in this furnace, but more recently three-phase current has been used successfully,*** and it has been found possible to operate such furnaces economically with alternating current of ordinary frequency, so that the necessity of building special and expensive generators is thereby obviated. The principal use for this type of furnace is in further refining the steel after it is blown in the converter, the additional cost of electric refining being more than compensated by the greater density and homogeneity of the product. It is also interesting news that by this method more than 1,000 tons of steel rails have been made and sold by the above iron works to German railroads.

Not only in the electro-metallurgy of iron and steel but also in other fields of electro-chemistry there have been many signal advances. Acheson's deflocculated graphite and Potter's "Monox" form the latest additions to the already large number of electric furnace products. The former of these is the result of Mr. Acheson's discovery that fine, pure graphite (which he succeeded in producing during 1906) when digested with water containing a trace of tannin becomes capable of remaining suspended in the water for an indefinitely long time, forming as it were a colloidal solution. In this condition, the graphite is designated by its inventor as "deflocculated," and the aqueous suspension has the singular property of being an excellent lubricant. When added to oil, deflocculated graphite reduces its coefficient of friction considerably. It therefore seems as if it will obtain important commercial application.

---

*Electrochem, Ind. VI, 493, Dec., 1908.

**Stahl u. Eisen, Nov. 6, 1907.
Electrochen, Ind. VI, p. 10, Jan., 1908.

***Electrochem, Ind. VI, p. 457, Nov., 1908.

Dr. Henry Noel Potter has obtained silicon monoxide by reducing silica at the temperature of the electric arc either by silicon or coke.* The temperature thus produced which has the formula SiO (analogous to CO), has been called "monox" by its inventor. In the air, it burns very readily to silica and this explains why it has not been obtained under the conditions existing in the carborundum furnace. In the furnace designed by Dr. Potter a mixture of sand and coke, or carborundum fire sand, is subjected to the action of an electric arc between two horizontal electrodes which are covered by the charge. As soon as the reaction begins, the monox vapor produced blows a funnel-shaped hole through the charge and is then chilled by contact with the walls of a large enclosed drum which covers the top of the charge. As this drum is practically free from air, the vapor does not burn but is condensed as a deposit on the walls of the container. The solid monox is a fine, opaque, light-brown powder which possesses many interesting properties. It has been found to be a valuable pigment in certain oil paints, in particular paints for brick-work and paints for protecting structural iron from rusting. It is also a good addition to black printing inks; and the probabilities are that many other uses will be found for it.

This completes our brief survey of some of the recent advances in electro-chemistry and electro-metallurgy. A great many things have necessarily been omitted; such as the work done by Edison and others on the iron-nickel accumlator; the electrolytic refining of lead, silver, and gold; the production of caustic soda and chlorine in the Townsend cell; the aluminium rectifier, and numerous other topics. But perhaps even the above few remarks may serve to show that not only has the development of electro-chemistry in recent years taken place in many directions that even the most imaginative scientists of twenty years ago did not foresee, but also the future will probably see more and more of the ordinary chemical and metallurgical operations replaced by electro-chemical processes. Especially will this be so for our own province, where, as well known, hydro-electric power is readily available, and there is an abundance of the choicest raw materials.

---

*Trans. Am. Electrochem Soc. 12, 1907, p 217,

FERTILIZERS AND THEIR MANUFACTURE*

F. K. HARRIS, '09

The object of a fertilizer is to supply to the soil those elements and constituents which the plants have absorbed in the process of their growth, and, generally speaking, there are three primary elements which need to be supplied, namely:

(1) Ammonia or nitrogen.

(2) Phosphate of bone containing about 50 per cent. free phosphoric acid.

(3) Sulphate or muriate of potash, sulphate being the best.

These three ingredients mixed with pure sand and water will stimulate the growth of vegetation, and as the sand has not the elements that will sustain plant life the test shows that the added fertilizer supplies the necessary food.

A rich land has all the elements to a greater or lesser degree, while a poor land lacks some, or nearly all, and some land will have all the elements but one. But no matter how rich the land is an addition of fertilizer generally proves a benefit, increasing the yield with the same labor. There are two general classes of fertilizers:

(1) Indirect fertilizers.

(2) Direct fertilizers.

An indirect fertilizer is one which does not in itself furnish directly to the soil any needed plant food, but whose chief value depends upon the power it has of exchanging unavailable into available forms of plant food. Those which are employed most commonly are lime, gypsum and common salt.

Gypsum, known also as calcium sulphate, or sulphate of lime, in some manner aids the process of nitrification, by which the ammonia and the nitrogen of organic matter are converted into nitric acid and nitrates. It also acts on the insoluble forms of potash and other elements of plant food, converting them into soluble and available forms. It is of value to such plants as clover and peas, etc.

Quick lime, or burnt lime, or calcium oxide, commonly called lime, change both the physical and the chemical character of soils. Freshly burned lime acts by decomposing vegetable and mineral matter already present in soil and changing them into forms which are available as food for the plant. Thus lime acts upon insoluble mineral substances containing potash and converts them into soluble forms. Lime aids in decomposition of animal and vegetable matter, such as vegetable mold, stable manure, etc., and tends to convert them into available plant food. Lime should be used along with other fertilizers.

Common salt has an indirect fertilizing value, which is mainly due to its power of changing unavailable forms of plant food into available, especially potash.

---

*Read before the Chemical and Mining Section of Engineering Society, Nov., 1908.

Hence we see if these were used alone the soil would soon become exhausted, and become of no value.

Direct fertilizers contain forms of plant food which contribute directly to the growth and substance of the plants. Such materials may contain either nitrogen or potash, or phosphoric acid compounds, or any two or all three of these forms.

Some of these direct fertilizers are:

Nitrate of soda, known as Chili saltpetre, found in Chili and Peru of S, A., contains 15½ to 16% of nitrogen.

Sulphate of ammonia is formed from waste products produced in manufacture of illuminating gas or coke. This contains about 25% of NH_3, which is equivalent to about 20½% of nitrogen.

Cottonseed meal is product form, after extraction of oil from cottonseed oil. This contains about 7% nitrogen, 3% phosphate and 2% potash.

Tobacco stems are refuse from tobacco factories, and consists of 5-8% potash, 2-3% nitrogen and small quantity of phosphoric acid.

Dried blood consists of blood obtained from slaughtering animals. It is prepared by evaporating, drying and grinding. This contains 10-15% nitrogen.

Dried fish scraps and ground fish are refuse from canneries and contain 7-8% nitrogen, together with as much insoluble phosphoric acid.

Meat scraps and tankage are slaughter-house refuse, dried and ground. Good tankage contains 10% or more of nitrogen and as much phosphoric acid.

Nitrogenous guanos are formed in dry regions. The Peruvian guano contained 7% of nitrogen, 7-12% phosphoric acid and about 1% potash.

Bones.—These consist mostly of calcium phosphate, which consists about 3/5 wt. of the bone. The remaining portion is a soft, flesh-like substance, called gelatine, which is rich in nitrogen. Bones which are used in making commercial fertilizers contain from 4-5% of nitrogen, and 20-25% of phosphoric acid, of which 1/3 is available.

A fertilizer largely used in Southern States at present is known as rock phosphate. The chief rocks which are used are apatite, caprolite and phosphorite. Until recently a large quantity of apatite was exported from Canada to Southern States from around Ottawa district for this purpose. But the discovery of the rocks of this nature having been made in the States the trade in Canada came suddenly nearly to a standstill.

In Southern States phosphate rocks are named by names which designate localities from which they come, as South Carolina rock, Florida rock, etc., and contain as much as 25-30% phosphoric acid. These rocks are in an insoluble condition, and of no use as they are. To make them available they are allowed to weather along with sulphuric acid, 100-lb. rock being treated with about 60 lbs. acid. This weathering takes from 4-6 months, in order that the rock may be thoroughly disintegrated. As much as 64% phosphate has been obtained in this way.

Market fertilizers contain, according to requirements for different plants for which they are used, from 2-8% NH_3, from 6-10% of bone phosphate and 4-10% potash, the balance being a filler, so that when a market product is mixed about these percentages of plant food are used with enough cheap ingredients, such as ashes and dirt, to make required weight and bulk.

Another form of fertilizers which has found its way into the market during this last century is the slag, which is run off from the basic furnaces used in the iron manufacture. These furnaces are lined with basic materials, such as lime, and during the blasting the lime absorbs the phosphorus from the iron forming the calcium phosphate. This forms the slag. It is run off while molten steam is blown through, which makes it porous and light.

This is now ground up and sold under the name of the "Thomas slag." It is very rich in the phosphates, the chief one being calcium phosphate.

This was first used in Germany and it is estimated that 1,000,000 tons are used yearly for this purpose.

An analysis of this slag is approximately as follows:

P_2O_5	-	16 20%
CaO	-	40-50
MgO	-	2-5
Si	-	6
FeO Fe_2O_3	-	8-15
MnO	-	5-11
Al	-	.5-.6
S	-	.5

We will now consider the manufacture of tankage fertilizer and bone meal from raw material to the finished product.

The raw material is obtained from packing houses, abbatoirs, slaughter-houses and butcher shops. It consists of the refuse from these places, such as carcasses of dead animals, offal and blood from slaughter-houses, bones and tallows and fats from the butcher shops and bye-products, such as meat scraps, etc., from packing houses. This is hauled either by teams or railroad to rendering works. Here the hides of dead animals are taken off and placed in the tanning room. The carcasses are quartered and placed in large iron tanks, which vary in sizes according to size of plant. The most modern ones are about 5-6 ft. diameter and 20-25 feet long, the capacity of these being about 10 tons.

The different kinds of refuse are placed in different tanks. The butcher bones and cattle heads are placed in one tank, the tallow and fat in another, and likewise the offal in another.

When the day's run is in these tanks, whose lids are screwed down in order to stand pressure without allowing any gas or steam to escape, the contents are cooked. This is done by allowing live steam from the boiler to pass in,

All pipes leading from the tanks being shut off by means of valves a pressure is created in the tank, which is allowed to run up from 15-20 lbs., denoted by means of a steam gauge. Under this pressure the length of time of cooking for different materials varies. A tank of 10 tons capacity, when filled with bones, etc., requires from 10-12 hours, while a tank of same capacity of offal requires about 8 hours.

After the cooking or rendering is completed pressure is allowed to go off. This escaping steam is laden with odors, which, if allowed to escape in air, would create a nuisance, hence a device must be had to do away with this.

Some plants lead their exhaust pipes through coils immersed in water, and from there lead into a cavity dug in the earth, where gases condense. Some lead the gases into a water tower, and there in contact with water some of them condense along with steam. while the remaining gases are drawn by a fan and are used for a draught for fires under boilers, there being burnt and allowed to pass out the chimney.

When pressure has all escaped the lid of tank is raised and the grease and oil are skimmed off. This is done by a pipe which is about ¾ way up the tank. In case the oil is lower than pipe liquor from another tank is pumped into the bottom, thus raising the oil.

After the oil has been taken off the tanks are drained of the liquor they contain. This is run by means of a pipe from the bottom of the tank into another division of the factory, called the wet tankage plant. This is done to each tank. After draining off the liquor from the tanks they are dumped. This is done by means of a slide attached to a wheel. They are dumped into vats. From here the bones from bone tanks go through the process of riddling while the offal and the carcass tank are washed with water, in order to obtain as much grease as possible, and then pressed in the hydraulic press.

The process of riddling which the bones undergo is similar to panning gold. The flesh on the bones after being cooked only slightly adhere to bone, hence may easily be separated. The riddle is a round vessel with a meshed bottom, each mesh being about 1″ square. A man shovels the cooked material into one of these riddles and then washes it under water by shaking. The flesh falls through the riddle and the bones are sent along to the drying room.

After being riddled the meat is then placed in an hydraulic press and pressed under a pressure of 120 lbs. for about 2 hours. This removes excess of water and grease and now the product is known as crude wet tankage. This tankage contains about 50-60% of moisture, and in order to make it into a product which could be shipped in bulk without any fear of decomposition the moisture must be reduced to at least 10%. To do this it is passed through what is called dryers. There are many types and descriptions. One of the oldest consists of a brick work enclosing a boiler. Pressure was kept up in this boiler to about 60 lbs.

The tankage was fed into a worm by a man and shovel. This worm led it to slot where it dropped, and by means of a long shaft fitted with paddles it was made to pass over the boiler. At end of first shaft it was dropped into another slot, where it was carried back by means of a shaft running in the opposite direction. Then it was returned by means of a third shaft and passed out containing from 6-10% moisture. This method was slow and continuous and required two men, one to feed it and one to take it away and keep up steam; hence it incurred a greater expense which the more modern ones do away with.

The more modern ones consist of an cylindrical iron vessel, about 6′ in diameter and about 18-20′ long. This is encased in another cylindrical vessel about 12″ greater in diameter.

The tankage is carried by means of a worm into the inside of the inner encasement until charged. The capacity of this ranges from 1,800 to 2,200 lbs., depending on nature of tankage. When charged the lid is placed on feed box and steam is turned on from the boilers. This steam enters between the two encasements and causes the moisture to evaporate from tankage as it comes in contact with encasement. The exhaust steam is let off. The water vapour from the tankage is carried away and allowed to condense in condensing chamber.

The length of time it takes to dry varies with the various kinds of tankage. If too much grease escapes previous operations it has a tendency to form in balls. This outer portion of ball will dry out and harden, while the inner portion will contain as much as 30% of moisture. This is one reason, other than that of value, why grease should be removed as much as possible.

The time it generally takes to dry is about two hours. When dry it contains about 8-10% moisture and is dumped and shipped as crude tankage to mixers, where it is mixed with potash, etc., as is needed by consumers.

In order that the tankage may be brought in contact with the hot encasement of the dryer the latter is fitted with a shaft runing through the centre. Connected with the shaft are paddles. These paddles revolve and carry with it the tankage. This serves also to prevent the tankage from forming hard lumps as previously stated.

The liquor from the tanks is run over to the wet tankage plant. Here it is allowed to settle in vats or cess pools. Any solid matter carried by the liquor settles to the bottom and any grease that has escaped rises and is skimmed off.

The liquor now is evaporated down to a semi-fluid condition in vacuum pans.

These are generally set up in pairs. The first pan is run at about 13 inches vacuo and the second effect at about 26 inches vacuo.

The vacuum draws the liquor into the pan from the settling vat by means of a pipe. Since the liquor is under vacuum pressure, the temperature required to boil it would be less than if it were boiled under ordinary conditions. Hence the exhaust steam from the engine can be used to do this.

In the first pan it is boiled down to a certain consistency (about that of cylinder oil) and then it is drawn over into pan No. 2. This pan being under greater vacuum will draw it from the first pan, and under this greater vacuum the temperature required to boil it is still less. Thus the vapour which comes off from the first pan is hot enough to evaporate the liquor in the second pan.

In the second pan the liquor is evaporated to the consistency of about 18° Beaumé, and contains 40-50% moisture. This is pumped when hot into barrels, or it may be fed into the dryer with the tankage. It contains a very high percentage of ammonia, and, in mixing it with the tankage, raises the quality of latter and consequently the value.

In some cases this evaporated liquor, or, as it is known commercially as "stick tankage," may be dried to a powder.

This kind of dryer consists in a revolving cylindrical vessel about 12′ feet long and 4′ in diameter. Steam is passed to the inside, and on side of this dryer is a pan containing the semi-fluid. As this dryer revolves it passes through the liquor, which adheres, and as it revolves the temperature of surface is great enough to drive off the moisture and dry the material.

On the opposite side is a knife, which fits closely to the dryer and scrapes off the dried material into a vat, from which it is placed in the storage room.

The fertilizer, as it now is, is sold to the manufacturers of mixed fertilizer and is sold on the basis of analysis. The two constituents which are of value are ammonia and phosphate of lime. The former being about twenty times more valuable than the latter, hence it is sold on so much per unit of ammonia and so much per unit of phosphate.

To make what is known as bone meal fertilizer the bones are cooked under pressure until they become porous and mealy. This takes about two hours longer than the previous operation. These are then treated similarly to the other fertilizer. It contains 20-30% bone phosphate of lime. The amount of phosphate of lime is estimated on amount which the land will absorb.

It was found that the amount absorbed by the land in course of time was equivalent to the amount which would be dissolved in an ammonium citrate solution. This, along with those phosphates which were soluble in water, were called the available phosphoric acid. But when the "Thomas slag" was used it was found that the ammonia citrate would not dissolve any of the phosphate, but that 1% citric acid solution would dissolve an equivalent amount. Therefore, instead of ammonium citrate 1% citric acid solution is used, and available phosphoric acid is the sum of phosphoric acid which is soluble in water and that soluble in a 1% citric acid solution. The nitrogen is estimated as ammonia by the Kjeldal's method. The nitrogen is changed to ammonium sulphate by means of strong H_2SO_4, and the ammonia is driven off by addition of KOH. The ammonia is caught in a known amount of standard acid, and the excess of acid being titrated off, the amount of ammonia can be calculated.

W. HODGSON ELLIS, M.A.M.B.

Dr. Ellis' connection with the School of Practical Science dates from the year 1878, when, on the organization of that institution, he became Assistant to the Professor of Chemistry, Dr. H. H. Croft. Prior to this, he had been a practising physician in this city, but this he gave up in the early seventies on receiving an appointment on the staff of the College of Technology, then located in the Mechanics' Institute building, the present Public Library. This College of Technology was the prototype of the School of Practical Science, now the Faculty of Applied Science and Engineering of the University of Toronto.

No professor of this Univeristy has won the respect and affection of associates and students to a greater degree than has Dr. Ellis. No professor's judgment on matters of academic policy was ever saner and no one's advice has carried more weight than has his. Of ripe scholarship, varied attainments, unexcelled honesty and broad sympathies, he has filled a place in university life larger than that which most men occupy. He combines to a very unusual degree a fine literary and artistic taste with rare attainments of a scientific character. His popularity was never greater than it is to-day and his colleagues and students sincerely hope that he may long be spared to continue the work which for over thirty years he has done so efficiently and honorably.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published Monthly during the College year by the University of Toronto
Engineering Society.

BOARD OF EDITORS

K. A. MacKenzie, B.A.Sc. '06	Editor-in-Chief
W. J. Bolton, '09	Civil and Arch. Sec.
L. R. Wilson, '09	Mech. and Elec. Sec.
A. Duff, '09	Mining and Chem. Sec.
R. J. Marshall, '08	Ex Officio U. T E. S.

Associate Editors

H. W. Price, B.A.Sc., '01	Mech. and Elec.
P. Gillespie, B.A.Sc.,	Civil and Mining
M. C. Boswell, M.A., Ph.D., '00	Mining and Chem.
W. Treadgold, B.A., '05	Railway

Advertising Committee

S. S. Gear, '08
T. H. Crosby, '09
R. H. New, '10
L. E. Jones, '11

Subscription Rates

Per year, in advance	$1 00
Single copies	20

Advertising rates on application.

Address all communications :

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

Editorial

T-o-r-o-n-t-o's Opportunity

It had been our intention to write at length on the duty of every Toronto graduate, and undergraduate, in Applied Science and Engineering to take full advantage of the Annual Meeting of the Canadian Society of Civil Engineers which takes place in our city during the last week of this month. The letter of Mr. W. J. Francis, which is published in full on another page, renders this unnecessary. Everyone should read it carefully. For many years "Toronto" men have not interested themselves in the welfare of this great society as they should. The credit for the wonderful advances the society has made in the last few years must to a great extent be awarded to our friendly rival, McGill University, and its graduates. There are probably special reasons for this not apparent to us; but with this convention comes Toronto's opportunity. Let us not be slow in seizing it. Every third and fourth year man should between now and the date of the convention seek to identify himself with the society as a student member and endeavor to attend every meeting. It is not too much to expect that the council will call off lectures in these years, so that not only the undergraduates but the staff may have an opportunity of attending all sessions.

It is gratifying to know the Engineering Society is going to entertain the national body. Let this dinner be a success. Every "School" man should lend his presence and enthusiasm in making it so.

The Ideal Lecturer

Attention is again called to the essay on "The Ideal Lecturer." A full discussion on this subject from the standpoint of the undergraduate cannot help but be interesting and must be instructive. While there will be as many "ideals" as there are idealists, it is probable that they can be readily divided into classes according as they view the aim of an engineering education. On the one hand are those who take for their motto, "Knowledge is power." These attempt to cover just as much ground as possible in a limited time. The extreme example is the lecturer who has thoroughly covered his subject. He rushes to his class and the blackboard and the entire hour is taken in a race to give and copy notes, which are afterwards memorized by the students. Everything has reached such a mechanical level that the personal equation of the lecturer is almost entirely lost. His place could be almost taken by lantern slides and a phonograph, with about as good results.

On the other hand there are those who claim that the ultimate test of a man's efficiency is not what he knows but what he can do, and that it should therefore be the aim of an engineering education to produce men who have the power to solve the industrial and engineering problems of the day.

Thus the lecturer must not only give his classes permanent possession of those kinds of knowledge which are most essential, but he must also teach them how to use that knowledge just as a mechanic is taught to use his tools. A mistake is made in giving the student more than he can ever assimilate. He should be taught how to meet and solve problems, so that he can go out into the great world with a confidence that he can solve its problems, one by one.

While the personal equation of the lecturer will always be the pre-eminent factor of his success, he must have the power of imparting his knowledge. He should have some idea of the psychology of teaching, for after all engineering faculties are schools, not colleges. A good engineer will not necessarily make a successful lecturer. The real test of a lecture course is the amount of benefit the students derive from it and consequently the lecturer should frequently apply the written test. These tests offer splendid opportunities of inculcating habits of accuracy, reliability, clearness of expression, and he should insist that the work be carried out in such a manner that these benefits will result.

Personally the ideal lecturer will be a thorough master of his subject. He will be clear and forceful in his delivery. His lectures will be logically developed, his language perfect, his blackboard work neat and accurate; his personality will be such that he will gain the good will and confidence of his classes; while firm he will clothe his lectures with an interest that discipline in a college class will be a negligible quantity. Should for some reason or other he lose control he will be big enough and strong enough not to take a coward's advantage of his class to vent peevish spite or biting sarcasm on the class either as a whole or on the individual who cannot hit back. He will be genial and sympathetic, easily approachable, and will always encourage his students to come to him with their knotty problems and at the same time will encourage in them a spirit of original research.

The Reunion Dinner

Since the last issue of Applied Science most of the plans for the Twentieth Annual Dinner have been completed, only some minor details have yet to be arranged. The Canadian Society of Civil Engineers have graciously accepted the invitation extended to them by the Engineering Society. This in itself will give our annual function more than its ordinary significance.

The graduates have taken hold of their end of the plans with an energy, a will, and an enthusiasm, they have never before shown in connection with any of our functions. Some of them, who are busy men, are taking a holiday and coming a long distance to be in Toronto for that evening.

Among the undergraduates also there is a real live enthusiasm. Every one feels that this event marks a new era in the history of the Applied Science Faculty, for upon the success of this enterprise, to a large extent, depends the amount of influence wielded by the Engineering Society.

A. E. Nourse, '07, is with the Expanded Metal Co. of Canada.

We regret to note the death of James McDougall, B.A., who was one of the School's earliest graduates, having graduated in 1884. A full obituary will appear in our April issue.

Messrs. Sinclair and Smith (both S.P.S.) consulting engineers, have rearranged their business arrangements and work will now be carried on under the name of Sinclair, Sutcliffe & Neelands. H. W. Sutcliffe and E. W. are both '07 men.

SOME RANDOM THOUGHTS FROM THE TORONTO GRADUATES' DINNER.

F. H. CHESNUT

At the St. Charles Hotel on the evening of January 13th, a number of graduates (about 50 in all) of the Faculty of Applied Science again congregated to discuss such points of interest as might be brought forward in connection with the improvements of the course in Applied Science at Toronto University and also to consider the means by which the standing of the Engineer in this country may be improved.

The following paragraphs give in substance the proceedings of the meeting and also the writer's views on the subjects under discussion.

The first matter brought before the meeting was a plea for higher standing of matriculation into the Faculty of Applied Science.

Many persons have commented on the fact, that a very large percentage of the students of the first year fail in their examinations. What are the causes of this? The question may be answered by either one or all of the following:

(1) The papers may be too difficult.

This is unusual and may be eliminated.

(2) The student may not take enough interest in his work due to either carelessness (which then puts him on his own responsibility) or due to his being discouraged by the amount of new work which confronts him. This latter would not be the case had he obtained a thorough working knowledge of Algebra, Euclid, Trigonometry and Analytical Geometry. The fact of the matter is that the jump is too great from the standard of the High School to the standard of the first year Science.

(3) The student may not be of sufficient age to grasp the subjects of the first year. The only solution of this difficulty is the establishing of a standard of admission in this respect.

There is still another side to the question. It is claimed that even if the standard of entrance be raised that no material difference would be shown in the results of first year examinations. It seems reasonable to admit that in the natural course of things the standard of the first year examinations would be automatically raised and if so there would still be the long list of tail-enders.

Considering both sides of the question it would then appear that the raising of the standard would not materially effect the number of successful candidates at the first year examinations, but it will be admitted that an engineer with a thorough grounding in the subjects spoken of (which are indeed perhaps the only subject he remembers after leaving college) is in a position to handle the average problem which he meets in practice.

RELATIONS WITH FACULTY OF EDUCATION

It was next brought to the notice of the meeting that the requirements for entry to the Faculty of Education were such that a graduate holding the degree of B.A.Sc. was not eligible while on the the other hand, a holder of the certificate of Senior Matriculation was eligible.

This seems a rather peculiar state of affairs but no doubt exists through an oversight on the part of the Council of the Faculty of Education, and needs but a suggestion to them to be rectified.

Along this line it might be suggested that demonstrators and lecturers of the Faculty of Applied Science be required to take a course in the Faculty of Education before being eligible for positions on the staff. It must be admitted that such a course might do a world of good and at any rate is worth a trial.

A good suggestion was next brought forward regarding the proposed study of English in the new course which is being formulated by the Council.

It was suggested that a system of English recitation be adopted, by which it was meant that the student would be required to write reports on different engineering problems. For instance, the Civil section might be required to make a survey of the Ravine and report on the feasibility of a bridge or an embankment across it, giving reasons for and against each proposition. Reports should be logical and concise, thus teaching the student the use of English in the practice of engineering.

MATHEMATICS IN ENGINEERING

Following this was a discussion as to the amount of higher mathematics which the average graduate carries away with him when he leaves the College Halls.

The speaker advocated a thorough working knowledge of Analytical Geometry and the Calculus.

There is no doubt that in many ways an engineer who can apply the Calculus would be master of many a situation; but it must be admitted that the brain with which most of us are provided is one of limited capacity; and it is almost a well known fact that the man who has his brain loaded down with numberless formulae is usually unable to apply a tithe of what he knows. We will admit, however, that there are exceptions. It seems more reasonable, however, to use the Calculus as more of a mind trainer than as a subject to be considered seriously in the everyday life of a practical engineer.

The Faculty of Applied Science does not attempt to turn out machines into which are fed problems and out of which come answers; it rather attempts to turn out men who by their college education have become fitted to handle problems in a logical, business-like manner. When the young engineer leaves the life of school to enter the school of life he should realize that he has not a formula to apply to each problem but better still a reasoning brain to apply to all problems.

We should realize as young engineers that we cannot all be inventors of new thoughts and methods; other great minds have gone before us and by thought and research have discovered and established certain facts and in many cases compiled them in the convenient Hand Book form. Hence, a close study of the Hand Books on different subjects would be of far greater benefit to the student than an attempt to become proficient in deriving Taylor's Theorem.

THE STATUS OF THE ENGINEER

The next subject brought forward is one which will no doubt be within the limelight in this country in a short time. It is that of protection by law of the Engineering profession.

What is required is legislation preventing any one from calling himself an engineer without first having passed the examination set by an Engineering Council appointed by the Legislature.

Is there any more reason why the country should be protected against incompetent men practicing medicine than against incompetent men practicing engineering? Why should the municipalities, the railway companies, private individuals, or any person or persons who employ an engineer be subjected to loss of life, property and money due to the incompetence of the engineer? But this state does exist and always will exist until the status of the engineering profession is established.

Again, the engineer of good standing must protect himself, for if one of his profession or one who presumes to call himself an engineer makes a blunder due to insufficient knowledge, the whole profession is lowered in the eyes of the employing public.

The matter has reached such a state at the present time that all engineering organizations throughout the country should rise up and demand legislation and should also see that the act is rigidly enforced.

Among those present at the dinner were: '88—C. H. C. Wright; '89—D. D. James, H. E. T. Haultain; '90—R. A. Ross, Montreal; '91—R. W. Thomson; '92—C. F. Mitchell; '93—A. F. Macallum, A. L. McAllister, W. J. Francis; '95—A. W. Connor; '99—W. A. Hare; '00—W. F. Evans, F. W. Thorold; '03—S. B. Wass; '04—E. Wade, W. G. McFarlane; '05—T. R. London, W. G. Swan; '06—C. B. Hamilton, C. S. Dundass, F. Barber, D. E. Beynon, F. M. Byam, J. O. Roddick, J. C. Armer, W. L. Amos, E. M. Wood.

C. C. Forward, '06, has been appointed to the staff of the Dominion Analyst, at Ottawa.

WANTED—A qualified O. L. S. and two experienced bush transit men. Apply H. T. Routley, Haileybury, Ont.

THE CANADIAN SOCIETY OF CIVIL ENGINEERS.

The University of Toronto.

Dean Galbraith.

Montreal, Jan. 6th, 1909.

My Dear Mr. MacKenzie: —

In connection with the coming Annual Meeting of the Canadian Society of Civil Engineers, I would suggest that "Applied Science" say some very important things in the January number and say them in the most pointed language at your command. For this event, to which we are all looking forward with much interest, committees are working and individuals are working. Applied Science, however, stands in a very different relation to the great body of students and graduates from that occupied by committees and individual members who must necessarily work by themselves. Applied Science speaks to all and on this occasion it should speak with no uncertain sound. This Annual Meeting of the Canadian Society of Civil Engineers will be one of the most important in the history of that organization,—an organization which may easily lay claim to being the most important scientific body in the Dominion of Canada to-day. To it practically all the engineers of this great Dominion belong, and the leading engineers of Canada will be at the meeting. The chief officer of this important body is our honored Dean. The students and graduates of the Faculty of Applied Science and Engineering of the University of Toronto owe it to the Society, to the University and to Dr. Galbraith to make the coming meeting an event which will long be remembered with pleasure by all who may have the opporunity to attend.

The Annual Meeting arranged for the 28th, 29th and 30th instants, is the only the second that has been called outside of headquarters of the Society at Montreal. On the former occasion in 1906 the first outside annual meeting was an unqualified success. The next meeting should be and will be a still greater success, and it is indeed gratifying to note from the official programme that the members of the Canadian Society of Civil Engineers are to be entertained by the undergraduates at the great school reunion on the 28th inst. This is "Toronto's" opportunity. It has been my good fortune for many years to have the privilege of attending meetings at the headquarters of the Society, and to have observed with great pleasure the manner in which McGill has thrown itself into the work of that organization. The high standard of the Canadian Society of Civil Engineers to-day is largely due to the unstinted labors of many connected with the staff of the great Montreal University. McGill has done what she ought to have done and she has left undone those things she ought not to have done and her efforts are appreciated. The coming occasion will be **T-o-r-o-n-t-o's** first opportunity to show her regard for the Canadian Society of

Civil Engineers and assert herself in the eyes of the engineering profession.

The occasion has still greater interest for the S.P.S. men. Our honored Dean will preside at the Society meetings in his capacity as President, and at the close he will hand the reins of office to a worthy successor. An unusual opportunity is thus afforded to all "School" men to show to Canadian Engineers and to the world at large in a very tangible way how highly they esteem and revere that man whose name is dear to every one of us. No truer heart ever beat in human breast. No better friend ever existed than he. Let us show our hand. The name Galbraith will go down to history as having occupied one of the high places in engineering education and it is gratifying to think that he is yet in his prime to appreciate the position he holds in the hearts of his students and his graduates, and the esteem in which he is held by the profession generally.

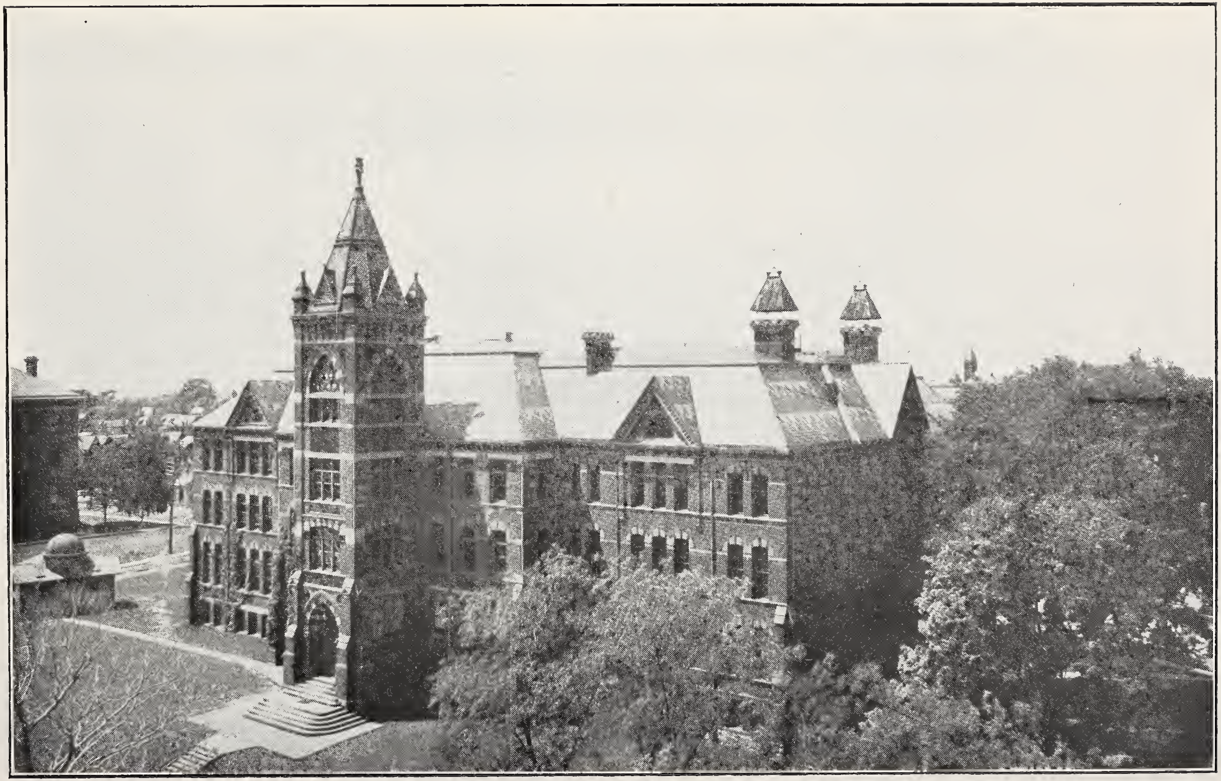
I wish you would point out also the importance of the continual attendance at every meeting of the coming Convention of every member of the School staff connected with the Canadian Society of Civil Engineers. This may seem at first a difficult to thing to do, but they should bear in mind that a great number of men will be present from all parts of Canada at great expense to themselves, and, in comparison with these, the staff members are under no expense whatever. The opportunity has never occurred before in such a broad way. It may never occur again. They owe it to themselves, to the Society, to the School and to the Society's President to follow this suggestion.

If time would permit, I should like to say a word to the graduates of the School concerning their connection, or, rather lack of connection, with the great professional engineering body of Canada. There is altogether too much indifference on the part of Toronto Engineering graduates toward the Canadian Society of Civil Engineers. Comparatively speaking, very few applications are put in, and too many of those who have attained the grade of Associate membership are content to remain in that class after they are long fitted to rank as full members in which grade they would be welcomed by the Society. There is no reasonable excuse for this. Branches of the organization exist, one might say—from ocean to ocean. In their own behalf and in behalf of the profession the graduates should take an active interest in the Society's affairs. Connection with the Society is a privilege and an honor all should covet.

In conclusion, let me again say that you cannot point out too strongly the importance of "Toronto" asserting herself by interest and attendance at the coming annual convention. The parties concerned are a great professional body, a great academical body and a great man—the Canadian Society of Civil Engineers, the University of Toronto and John Galbraith.

Yours sincerely,

WALTER J. FRANCIS.



ENGINEERING BUILDING, UNIVERSITY OF TORONTO
The old school which must soon be replaced by a larger and more modern structure

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 FEBRUARY, 1909 New Series Vol. 2, No. 4

APPLIED SCIENCE DINNER.

A. D. LePAN, B.A., Sc.

On the evening of Friday, Jan. 31st, 1890, the first annual dinner of the Engineering Society of the then School of Practical Science was held at the Hub where, in all, 54, including guests, Faculty, graduates and undergraduates, formed a company who though optimistic to the fullest degree, little dreamed to just what proportions this little affair might grow.

Twenty years later some of the same men and a "few" others sat down to another dinner held by the same Society of the now Faculty of Applied Science of the University of Toronto. Before going further some may ask: why speak of the dinner of 1909; for every graduate or undergraduate attended it or should have attended it, and to those who did, every event of that evening is and will remain for many years as clear as at the time of happening. In a large measure this is true, but still there are those who were unable to be present, though perhaps deeply interested in the Society, and to these and to posterity we owe some record of one of the evidences of the admission of this Faculty to its proper place in the University and of its immeasurable influence, wielded through its graduates, in every phase of national life.

Many circumstances this year tended to make this the largest dinner and most noteworthy social function ever held in connection with Applied Science in the University of Toronto. First, there is that exuberant and deeply rooted spirit of loyalty which every School man bears to his University as evidenced by his attitude towards his Alma Mater, its Faculty and all associations connected with them. In the days of the "Ink" age this spirit was manifest in the readiness and eagerness with which he cultivated his artistic sense at the expense of his opponents, but to-day, through assimilation, this much abused fluid of other days flows through saner channels tracing on its course an indelible record of growth substantial and lasting, of appreciation genuine and sincere and of acknowledgment of our greater responsibility and privileges through this growth.

Then, too, the Canadian Society of Civil Engineers met in

Toronto and the Engineering Society was fortunate in having as its guests 200 of the members of this sister society. The circumstance was all the more auspicious since Dr. Galbraith, as President of C.S.C.E., delivered on the evening of the dinner, his valedictory address dealing, in masterly detail, with engineering problems of to-day ; and in no small measure was this dinner intended as a personal tribute to Dean Galbraith and Dr. Ellis, two of the charter members of this Society who through years of faithful and untiring service have endeared themselves to each succeeding graduating class. Considering all these facts, it is little wonder that the advent of the School dinner was eagerly looked forward to on all sides.

As early as 7.30 intending diners commenced to arrive, those of older years to be present at the Canadian Society meeting, and the more frivolous youth to roam the corridors which first resounded with his clear and blithesome "Toike Oike" and later with his almost agonized appeal for dinner, for, in the excitement, caused by the change from the short blue jumper, which now hangs in the laboratory, now forms a missile intended for some industrious embryo engineer and now as a duster for the School boilers as its prisoner blinkingly treads these oft-explored passages, to the silk lined flowing garment, emblem of social pleasure and obligation, many an expectant youth had forgotten the commoner things of life and now awaited the opportunity of presenting himself at the festive board for the third time that day, or possibly the second for to many breakfast is often "run fast" from bed to lecture. Under these circumstances it is recognizable that when the doors of the banquet hall were opened at 9 p.m. and the guests and more privileged persons had gained admission, that some slight anxiety might be manifest on the part of the undergraduate body to satisfy the natural demands of the inner man. Evidence of this was obtained, if in no other way, from the over-turning of a row of chairs in Convocation Hall and the releasing of a door from its normal position in spite of the efforts of the genial Christie and our own "Jock," but soon the good-natured crowd were all in the banquet hall with the exception of about 40 who for lack of accommodation were forced to sit down in the tiled corridors of Convocation Hall.

The drafting-room transformed into a banquet hall could hardly be recognized by the embryonic engineers who strugggle in vain to keep the dread "See Copy" off their alleged works of art and engineering skill, for in the place of solid rows of sombre work tables, the room is filled with long tables draped for the present in spotless white and decked with a profusion of flowers rarely seen by the engineer who with long boots and almost longer whiskers tramps the wilderness, drawing imaginary lines, or who, with grimy hands seeks to solve the mysteries of the invisible and illusive "'current." Extending the full length of the hall we have the guests' table and on the wall over its centre a huge shield of welcome draped with a profusion of flags.

Directly opposite on the other wall we see amid a mass of flags and bunting, a portrait of Dean Galbraith. But this transformation did not in the least seem to perturb any of those present and soon with amazing rapidity all were invited to partake of a menu "I am part of all that I have met" which diverted the attention of even the most aesthetically inclined to the baser yet essential things of life. During the serving of an excellent repast the sense of humor of the man, who had not partaken of the necessaries of life since his regular noon-day struggle with a so-called sirloin or his perhaps indelicate queries as to the contents of the indeterminate Hamburg steak, began to rise; much hilarity was indulged in and as the meal progressed these individuals accepted with the utmost grace their ice-cream as a filler between the reverse side of a plate and the erstwhile spotless linen.

But all pleasures must end and this as others did, only to be succeeded by pleasures of different forms, for with the tables cleared and with the man who believes it is better to smoke here than hereafter indulging, President Marshall, chairman of the evening, proposed the toast to the King. He then introduced a second toast of the evening—"Canada" and connected with its proposal A. D. LePan who, in a brief speech, dealt with the comparisons between the past and present in the engineering history of this country, the transportation problems and possibilities of increased activity along engineering lines as evidenced by the prevailing excellent financial conditions, and introduced in reply Byron E. Walker, Esq., as "A man who fingers with a touch, perhaps the most sensitive in Canada to-day, the throbbing pulse of Canadian life and conditions."

In rising to reply, Mr. Walker was enthusiastically received, and immediately won the closest attention and interest of his hearers. He outlined with vigor his belief that the young men of to-day, and especially the engineers, should study as well as development, a conservation of Canada's resources from the grasping need of a world which is rapidly becoming poor in the very iron, timber and other treasures of which Canada has such stores.

"A great trust has fallen upon you young gentlemen," said the speaker. "Do not be proud of Canada because you are Candians, but because the trust falls upon you to develop and conserve our wealth. We and you shall be judged some day by the use we make of it. We in Canada are in great danger to-day. No other country of only 7,500,000 people has such great resources and has at the same time lying to the south the most profligate user of natural resources in the world and one which to-day has practically exhausted all that it once possessed. Our problem to-day is not to develop Canada's wealth, but to conserve it. If it be true that in a comparatively few years the iron and timber of the United States will be exhausted, do you think that when that time comes we shall be allowed to enjoy our own resources at our leisure? The United States will turn like lightning upon them and devour them as fast as it can. So I say learn to conserve what we own. If we do in future centuries Canada will be master of the steel trade and rich in lumber and water powers. All the nations will have to come to her. If you do not, if you cannot awaken your own consciences and the conscience of the public to the menace of our timber, our water ways, our fisheries, and our farm land which lie in the demands of a profligate age, you will have occasion to glory in being cowards. You will have been false to your trust."

The deep interest with which these remarks were received showed that the speaker had indeed struck a responsive chord in all his hearers and had impressed them not only with the glorious heritage which is ours, but also with the responsibilities which ownership of this trust involves and with the fact that conservation should not be sacrificed to development.

In proposing the toast to the University W. B. Redfern, '08, in an excellent speech, eulogistic of President Falconer, said in part:

"Speaking on behalf of the undergraduates, the graduates, and I believe on behalf of every member of the staff as one Faculty among several others in this great University, we hope that we may all be so harmonized and blended in spirit and aim, that the day is past when it was natural for one Faculty to work in isolation and aloofness and that instead even over past prejudice, past jealousy and past traditions we may have an interchange going on in increasing measure, an interchange that helps him who gives and him who takes, an interchange in which each Faculty is the gainer, in this way making our University truly one integral and unanimous whole.

"The interests of education are in these days so closely bound together that a gain anywhere is a gain everywhere and the feeling which unites universities in all parts of the world by common interest in the advancement and dissemination of knowledge is growing stronger year by year. As one university in the great sisterhood of universities in Canada, we hope that we may all be so refined in spirit and aim, that we may be the embodiment of an ideal which will eventually give to this young and fair dominion the noblest and truest type of citizenship and that it may truly be said of us that we are discharging our duties and measuring up to our responsibilities, in other words, gentlemen, if weighed in the balance, we hope we shall not be found wanting."

From the reception tendered to President Falconer, who replied to this toast, there can be no doubt as to the respect and esteem with which he is held by the graduates and undergraduates of the University of Toronto. Cheer after cheer greeted the speaker and it was only to sing the parody

F-A-L-C-O-N-E-R-!
That's the way you spell his name,
Astray you can't go far,
When you hear it,
How we'll cheer it,
Everywhere we are.
F-A-L-C-O-N-E-R-!

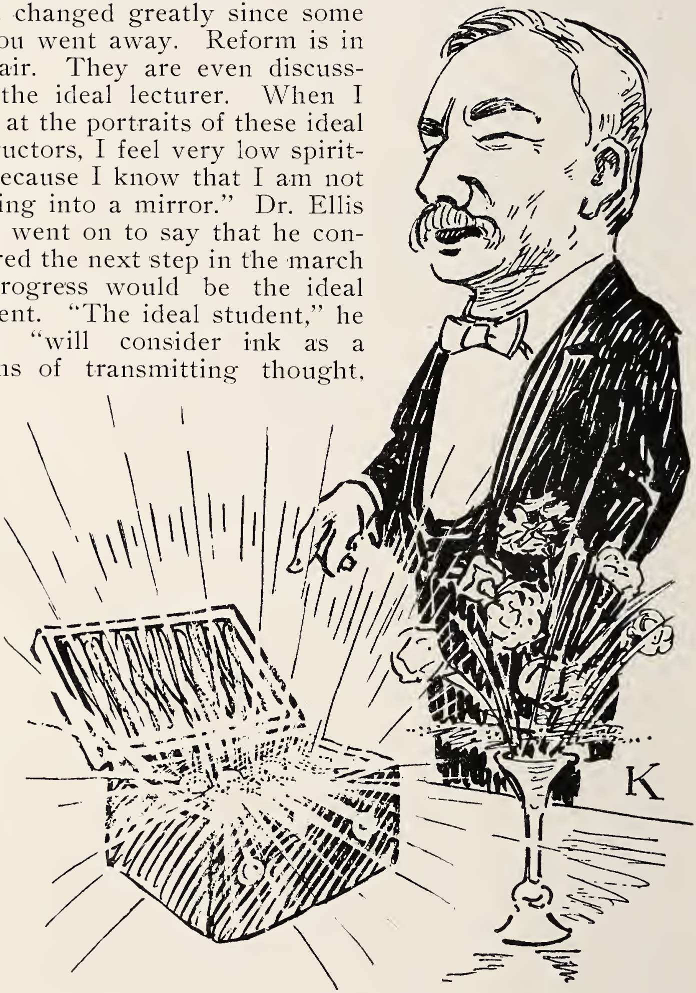
flashed on the screen that anyone desisted. It is fortunate that such demonstrations do occur for there are times when in a moment of thoughtlessness the action of the undergraduates belies his thoughts and respect apparently finds no place in the category of his attainments. But this reception rang true and clear and was indeed a tribute to the man who by his fairness, his masterly control and scholarly attainments has in so short a time endeared himself to the University of Toronto. After this spontaneous reception, President Falconer's address was listened to with rapt attention.

President Falconer has since coming to Toronto shown himself to be one of the happiest speakers we have. He always speaks briefly and he always has something to say that his hearers go away determined to remember. On this occasion he spoke with his usual brevity and impressiveness urging the undergraduates present to bear in mind the advice they had received from Dean Galbraith, that the importance of the man has to be considered as well as that of the engineer and that self-control is absolutely necessary. He told of crossing the ocean a couple of years ago and of observing the splendid discipline of the ship under a cheerful and observant captain with whom he had several pleasant conversations. In the management of that ship every man played his part all under the direction of this one quiet and competent man. "The master of that vessel," he said, "was Captain Sealby who showed the world the other day the strength that self-control gives a man over himself and others." President Falconer, on behalf of the university, extended a warm welcome to all the graduates, the majority of whom he had never seen, as they received their degrees before his term of office began.

Then followed one of the most pleasant events of the whole evening, the chairman intimated that Mr. J. L. Morris, the first graduate of the School of Practical Science was present and that gentleman after dealing in interesting comparisons between the School of the past and present noted that through all this growth and transformation could be seen the guiding hand of men who even in his days had labored unselfishly under most adverse conditions that their ideal might be realized. It was indeed gratifying that these men should see their most optimistic hopes fulfilled and fitting it was that those who had received so much through personal contact with these men and through the realization of their ambitions should be privileged to show their appreciation. When he presented to Dean Galbraith on behalf of the graduates in Science, a cabinet of silver, enthusiasm knew no bounds. When the chorus of "He's a Jolly Good Fellow" and "What's the matter with Johnnie?" "He's all right" died away, Dean Galbraith feelingly thanked the graduates, modestly associating with the success of the School many able assistants who had worked with him on the staff.

In a happy speech of eulogistic reference, Mr. J. W. Tyrrell, of the class of '84, presented to Dr. Ellis a beautiful gold watch and chain, also on behalf of the graduates. Again enthusiasm arose to the extreme, and Dr. Ellis did not belie the chorus "See him smiling."

"I never saw so many of you together before," said Dr. Ellis, when he arose to speak. "Things have changed greatly since some of you went away. Reform is in the air. They are even discussing the ideal lecturer. When I look at the portraits of these ideal instructors, I feel very low spirited because I know that I am not looking into a mirror." Dr. Ellis then went on to say that he considered the next step in the march of progress would be the ideal student. "The ideal student," he said, "will consider ink as a means of transmitting thought,



Dean Galbraith was presented with a cabinet of Silver not as an agent for decorating his fellow beings, he will look upon snow as a wonderful form of water rather than a missile. His taste for music will be so cultivated that he will not convert the furniture of the lecture room into sounding brass and tinkling cymbal." The speaker then turned the drift of his conversation in his usual happy manner, "but I find that that student is already here," he said. "He is the man who goes out and wins fame and riches in his profession and then comes back and gives most of the credit to his old teachers."

After the presentations the spirits of the audience were raised to such a pitch that they felt it necessary to have a song from Hugh Ritchie. Accordingly the big fellow, in spite of his struggles, was hoisted on a table and kept there until he rendered three stanzas of "Stop your tickling, Jock," in the most approved style to the great delight of all present.

The chairman then called on P. R. Brecken, '08, to propose the toast to "Our Guests." He spoke of the privileges of entertaining such distinguished guests as the Members of the Canadian Society of Civil Engineers, and of the intimate relation of the Engineering Society as a feeder to the more mature Society. The importance of the engineer in moulding the destinies of this country was emphasized, for on him as much as on the financier depends the support accorded by the investing public. Upon his good judgment and ability are often dependent the lives of hundreds of human beings, not to mention the safeguarding of thousands of dollars. In the matter of reports he must be a man whose one idea is to serve in the most efficient manner or he will often be influenced to make his power subservient to the selfish interests of the few.

Mr. George A. Mountain, Chief Engineer of the G.T.P. and President-elect of the C.S.C.E., in reply, referred to the development in the profession and emphasized the importance of maintaining that high standard so essential in the varied interests of engineering. He also referred to the gratifying growth of the Society and spoke in optimistic terms of its future.

Mr. Kennard Thomson, one of the founders of the Engineering Society, introduced by the chairman as a Scotchman, spoke very happly about the growth of the School and the pleasure that visits of a nature such as this afforded the older graduates. He spoke briefly of the formation of the Engineering Society and stated how utterly impossible it would have been to have formed a Society "but for the encouragement and guiding hand of that incomparable man, Dean Galbraith." He also spoke in a highly complimentary vein in regard to the work of Dean Galbraith on the Bridge Commission and deplored the fact that in New York for some of the investigations then under way, commissions of such a calibre had not been appointed. As a School man, now resident in New York, he spoke in no uncertain terms of the esteem in which our engineers are held and the reception accorded to Canadian engineers who decided to desert their native land

and cast in their fortunes with those of the neighboring Republic. "Another reason why Canadians are liked in the States is because they are always loyal to the land of their birth, to the land of their adoption, and to the Anglo-Saxon race." In closing, Mr. Thomson extended a most cordial invitation to all to visit his office when in New York, for "we are always glad to see Canadians."

R. A. Sara, '09, in a humorous and entertaining speech, proposed the toast "To Our Graduates." In a happily used illustration from Mark Twain he emphasized the need of scientific training, and as an evidence that this Faculty is ably meeting the demands made upon it, indicated with pride the graduates present, who, endowed with the engineering knowledge obtained at the School, had gone forth and in a world of men are doing men's work. He also expressed the hope that the undergraduates would maintain the high standard set in engineering practice.

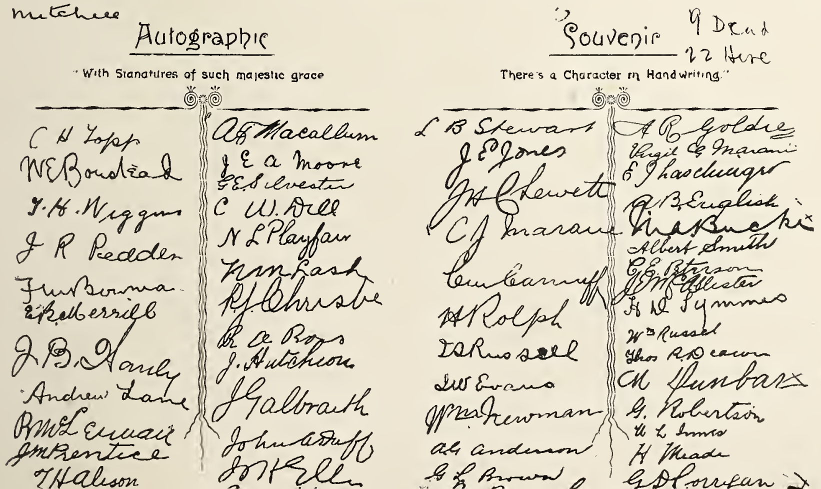
Geo. A. Mountain, C.E.
President Elect Canadian Society Civil Engineers
Courtesy of "Construction."

A high tribute was paid to Mr. C. H. Mitchell, who replied, for although late his very interesting address was listened to with close attention. He spoke very entertainingly of the first Engineering Society dinner and showed a slide of the menu used on that occasion, which is given below. His speech is given in full elsewhere.

Mr. L. E. Jones, '11, in a brief speech, proposed the toast to "Sister Institutions," and after replies by different representatives, the company sang the National Anthem and broke up about 1.30 a. m. During the evening musical numbers were rendered in excellent style by an octette, composed of Messrs. W. C. Blackwood, A. A. Kinghorn, J. Stuart, H. Stuart, W. Boulton, J. Craig, J. McKinnon, A. Sedgewick, and by Messrs. F. H. Chestnut, E. V. Chestnut, V. S. Chestnut, H. F. Secord in an orchestra with W. C. Collett as pianist and C. E. Bush as conductor.

T. K. Thomson

This feature was indeed a most acceptable contribution to the evening's enjoyment, as evidenced by the unstinted applause accorded the rendering of each selection. Needless is it to say, that in every respect the dinner was an unqualified success and too much credit cannot be given to the Committee who so ably assisted by Professor C. H. C. Wright and Mr. T. H. Hogg, demonstrated the feasibility of a function of such magnitude.


Mitchell

Autographic Souvenir

9 Dead
22 Here

"With Signatures of such majestic grace
There's a Character in Handwriting."

C H Topp
W E Boustead
T. H. Wiggins
J R Peddie
F W Bowman
E K Cotterill
J. B. Hardy
Andrew Laine
R M L Ennatt
J M Prentice
T H Alison

A B Macallum
J E A Moore
G E Silvester
C W Dill
N L Playfair
H M Lash
R J Christie
R A Ross
J. Hutcheon
J Galbraith
John A Duff
J M Ellis

L B Stewart
J E Jones
J H Clewett
C J Marani
C M Canniff
H Rolph
T A Russell
J W Evans
Wm Newman
A G Anderson
G L Brown

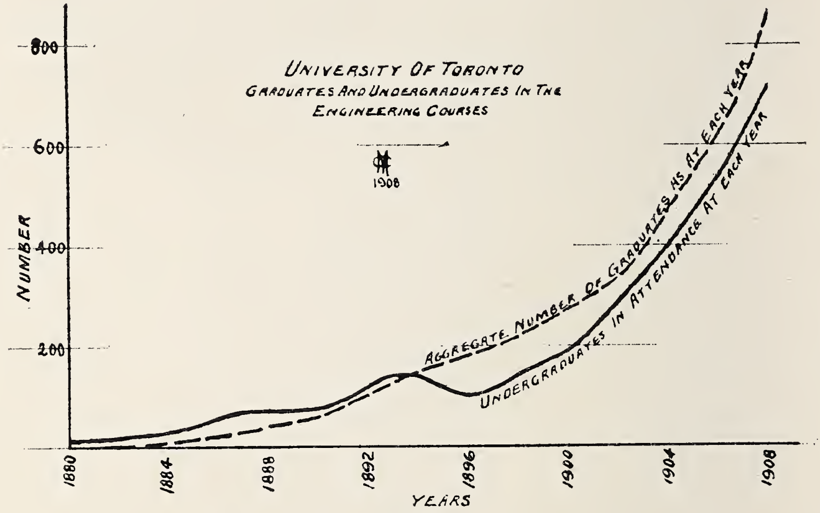
A R Goldie
Virgil G Marani
E F Haschinger
A B English
M A Buckie
Albert Smith
G E Patterson
J W McAllister
H D Symmes
Wm Russell
Thos R Deacon
C H Dunbar
G. Robertson
W L Innes
H Meade
G D Corrigan

THE ENGINEERING GRADUATES—A RETROSPECTION

CHARLES H. MITCHELL, C.E. (Tor.), '92.

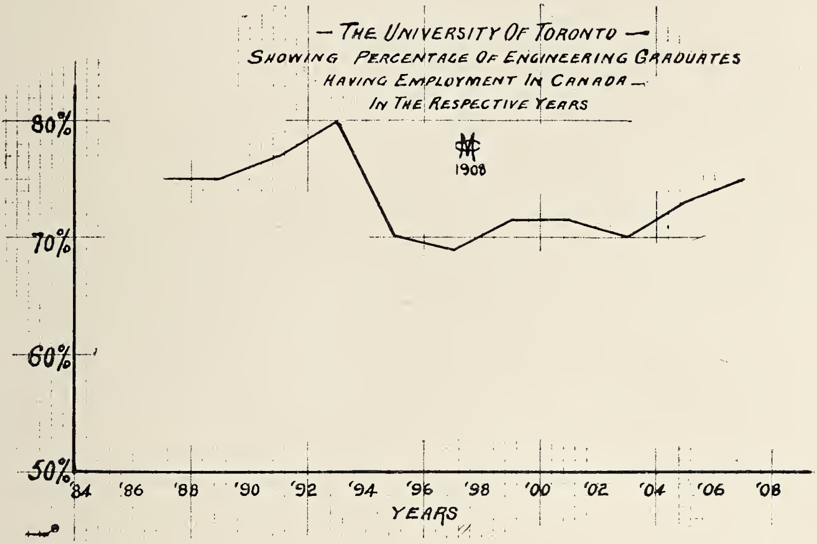
The reunion of graduates of the School of Practical Science and of the University in engineering at the recent banquet was an occasion to afford considerable retrospection. Perhaps the term and process of introspection might also be included as part of the operation of interviewing and inspecting ourselves as we hundreds of graduates of the past quarter century came together from the four quarters of the Dominion.

During the few days of the reunion and the hours of the banquet itself, the numerous groups of graduates intent upon each other after long separation, betokened the sifting out of many years' aggregate of experience and happenings. By the end of the period the sifting process was well advanced, the sizing and the classification of the various experiences being so complete that one so inclined could begin to find real mathematical laws and in some cases, almost actual formulae, by which the various graduates' work could be represented. That sounds academic perhaps, but there is "but little here below" that modern engineers cannot reduce to a science even if they are such vague matters as the wanderings of the peripatetic graduate, his various tastes for work and his probable earning power.

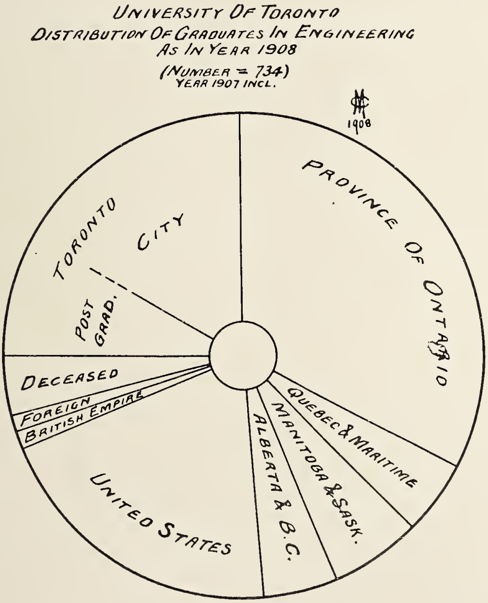


No. 1

It was with some half formed notions along these lines that, when, being honored with the request that I reply to the toast of the graduates at the reunion banquet, I assented and set myself


— The University Of Toronto —
Showing Percentage Of Engineering Graduates
Having Employment In Canada —
In The Respective Years
MC
1908
80%
70%
60%
50%
'84
'86
'88
'90
'92
'94
'96
'98
'00
'02
'04
'06
'08
YEARS

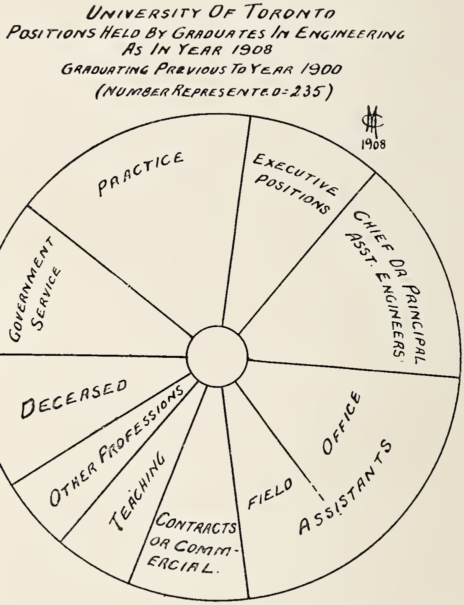
No. 2


University Of Toronto
Distribution Of Graduates In Engineering
As In Year 1908
(Number = 734)
Year 1907 Incl.
MC
1908
Province Of Ontario
Toronto
City
Post Grad.
Deceased
Foreign
British Empire
United States
Alberta & B.C.
Manitoba & Sask.
Quebec & Maritime

No. 3

the task of trying to represent the characteristics and movements of our graduates by graphical means. The novelty of this was my sole excuse for adopting such a means of delivering an after-dinner speech. The use of the lantern slide and screen as a medium of after-dinner speaking will, I hope, commend itself to the profession by reason of its practical features and its dumb eloquence so well adapted for service by the "Silent Faculty."

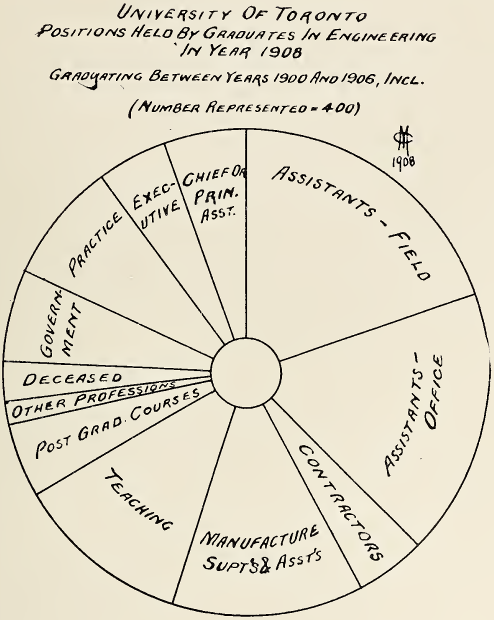
If an apology is needed for presenting the various graphical productions which follow I can only repeat that I believe this method of representation will more readily than any other, bring home to the university authorities and to ourselves the growing importance of the Engineering courses in the University of Toronto and the very intimate connection between its graduates and the vast country which we are all so busily engaged in developing.



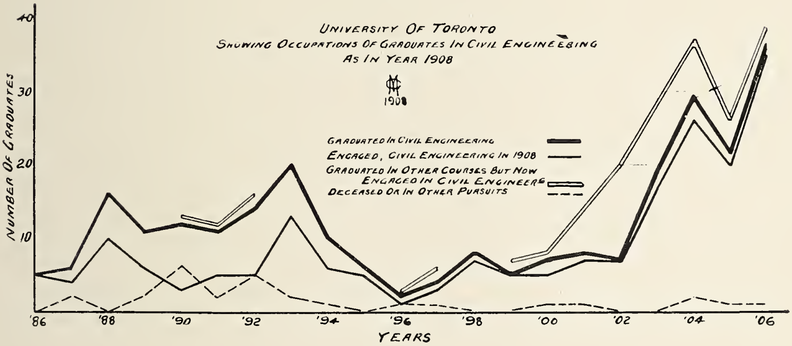
No. 4

The broken line shows the aggregate number of graduates up to any year while the full line shows the number of undergraduates in attendance in that particular year. The former is always increasing, the latter may vary. Note the extraordinary coincidence of the increase of students in attendance at the same rate and number as the graduates. This shows the rapid growth of the faculty.

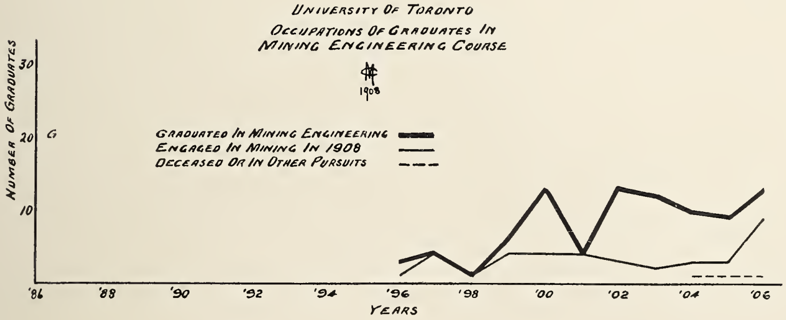
The percentage of graduates finding employment in Canada as the years progress. The curve is obtained by finding the


University Of Toronto
Positions Held By Graduates In Engineering
In Year 1908
Graduating Between Years 1900 And 1906, Incl.
(Number Represented = 400)
1908
Assistants - Field
Assistants - Office
Contractors
Manufacture Supt's & Asst's
Teaching
Post Grad. Courses
Other Professions
Deceased
Govern-ment
Practice
Exec-utive
Chief or Prin. Asst.

No. 5


University Of Toronto
Showing Occupations Of Graduates In Civil Engineering
As In Year 1908
1908
Graduated In Civil Engineering
Engaged, Civil Engineering In 1908
Graduated In Other Courses But Now Engaged In Civil Engineering
Deceased Or In Other Pursuits
Number Of Graduates
40
30
20
10
'86
'88
'90
'92
'94
'96
'98
'00
'02
'04
'06
Years

No. 6

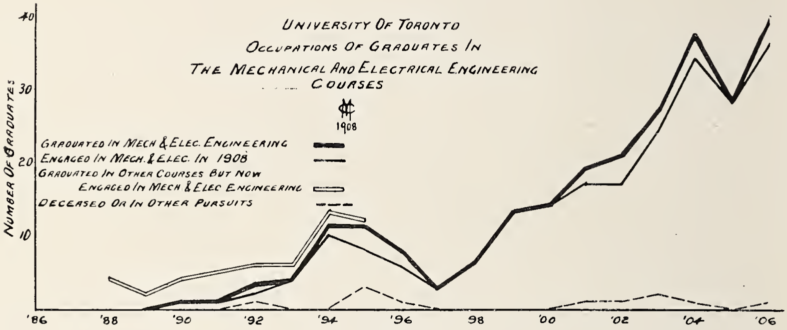

University Of Toronto
Occupations Of Graduates In
Mining Engineering Course
1908
Graduated In Mining Engineering
Engaged In Mining In 1908
Deceased Or In Other Pursuits
Number Of Graduates
30
20
10
'86
'88
'90
'92
'94
'96
'98
'00
'02
'04
'06
Years

No. 7

percentage of graduates as registered in the School calendars from year to year, commencing in 1884. The financial depression of 1893 in the United States is clearly shown by the large percentage (80) of graduates who returned home to Canada and as the better times came the percentage remaining rapidly decreased until late years when it is increasing in a very marked manner due to the large works now in progress in this country.

Based on the graduates list in the Calendar of 1908 comprising the 734 graduates up to and including those of 1907.

4 Based on the list in Calendar of 1908, representing 235 graduates. Note that half the number of these older graduates were engaged in Government service, practice, executive positions and as chief or principal engineers, while those who were assistant engineers were less than a quarter of the whole.



No. 8

5 Based on the list in Calendar of 1908 comprising about 400 graduates between 1900 and 1906 inclusive. In this the four divisions named in diagram No. 4 constitute only a quarter of the whole while the assistants are over a half.

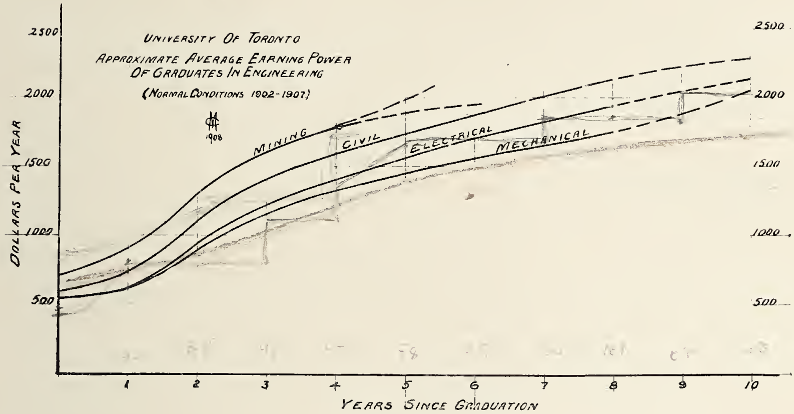
This diagram 6 represents a concise history of the graduates in civil engineering year by year. The heavy full line shows the number of graduates in civil engineering in each year. The light full line shows the number of those of each year who, in 1908, were still engaged in civil engineering work, the remainder (i.e., represented by the space between these two curves) being either deceased or in other pursuits than engineering. The broken line shows the number of those deceased or in other pursuits. The double line, or rather the space between the double line and the heavy line, represents those graduates who were educated in other courses than civil engineering but who in 1908 were engaged in that branch of work; note this large increment between 1900 and 1905.

The fairly uniform number graduating in the civil course between 1888 and 1894, the small number between 1896 and

1902 and the rapidly increasing number since 1902 are to be noted as indicating development of the country.

This is drawn on similar lines to that of civil engineering. This course was instituted in the early 90's. It is to be noted, however, that there has been a very remarkable departure of graduates in mining from their specialty between 1899 and 1905, most defections being to the civil engineering as indicated in Diagram No. 6. This fact reflects the conditions of the country at that time. There had been a mining boom previous to 1900 which quickly died out and only within the past few years has activity in this branch of engineering again occurred. This is shown in the rapidly rising line at the end.

This diagram is similarly constituted to those of the other branches. The first graduate in this course was in 1890 and with the exception of the depression in 1897 common to all courses, the number of graduates has rapidly increased to the present. It is agreeably noticeable that nearly all graduates in this course have remained engaged in this branch and specialty and that the deaths and departures to other pursuits have been very small. The increment from other courses between 1888 and 1895 is due to the fact that in these earlier years there was no course in the School in mechanical and electrical engineering and this increment is composed of men who graduated in civil engineering.



No. 9

This diagram is offered for criticism and discussion with some misgivings. It will probably appear to be a very audacious method of indicating the dollars and cents side of the professional career of the young engineer. It must always be remembered, however, that the curves indicate the probable average earning power and that there are many exceptions to them, exceptions in the matter of high salaries and other emoluments which are well known amongst the graduate body.

These have been compiled having regard to the approximate earning power of the man and the money value of the position which he fills. Consultation with numerous graduates of different periods who are well acquainted with their fellows has formed the basis of the general trend of these curves, but at best they are of course the merest approximations, as no definite law can be deduced especially after five or six years out of college.

The mining graduate is undoubtedly the better paid immediately after graduation, largely due to his location and to the larger ratio of his muscle value to brain value. After four years, however, the miner appears to vary considerably and there are instances of mining graduates of five or six years' standing who are earning twice the amount indicated herein at that time.

All courses run fairly parallel the first two or three years with a rapid rise in all in the second year. The civil and electrical men run evenly side by side, the curves after six or eight years tending to flatten, although the electrical may trend upwards again with time as the graduate gets business connections of a larger horizon.

The mechanical graduate is apparently the most poorly paid in the first six or eight years, but after that period there is every indication that, as he begins to get an interest in the business with which he is connected, his curve rises steadily and, as he becomes a "manufacturer" in the broad sense, it will doubtless cross the other two curves. This is gratifying because it is an incentive to the young men to follow mechanical engineering pursuits in order to become manufacturers and thus provide what this country is most in need of.

It is hoped that this diagram will bring out considerable discussion and if the truth is to be told, it was largely with this in view that it was prepared.

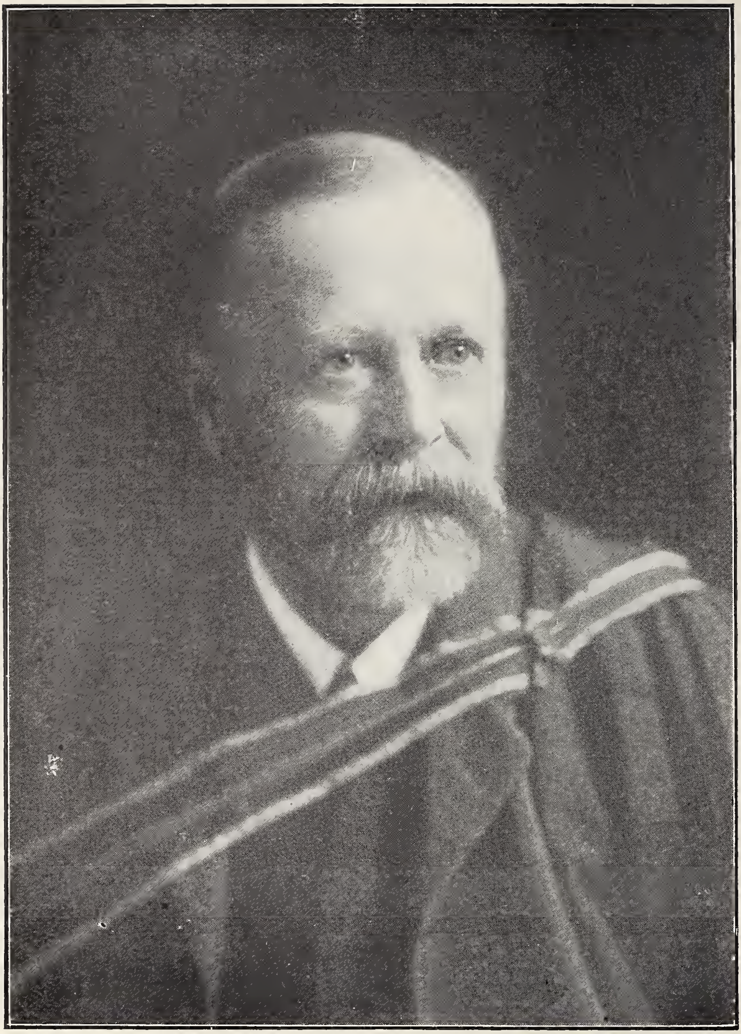
HISTORY OF SCHOOL OF PRACTICAL SCIENCE.

W. HODGSON ELLIS, M.A., M.B.

Until the middle of the nineteenth century no attention was paid in England, and very little in America to the organized teaching of science and in particular to science in its applications to industry. Up to that time chemistry had been looked upon only as a part of a medical curriculum; engineering (other than military engineering) was learned only by apprenticeship; mineralogy and geology were not taught at all. The Exhibition held in 1851—parent of a numerous progeny—directed public attention in England to the possibilities of scientific invention and scientifically directed industry. The interest so awakened took the form, in the first instance of an attempt to teach elementary science to the artisan. This movement, of which South Kensington is the symbol, was called "Technical Education." It was begun with much enthusiasm. It gave rise to some disappointment. The efficiency of the British workman was not found to be perceptibly increased by his listening to lectures on technical science given by lecturers who often knew little of science and less of technology. Of course, much of the instruction was of quite a different character and excellent work was done in certain cases. On the whole, however, the results of this popular education did not come up to the expectations of its promoters.

In the United States scientific education followed the German model more closely than in England. There institutions after the model of the German Technical High Schools—that is, training schools for engineers and chemists—were established with most satisfactory results. When the need for technical education began to make itself felt in Ontario a commission consisting of Dr. I. G. Hodgins and Dr. McHattie was sent by the Provincial Government to study the question in the United States and Europe. As a result of their report a bill was introduced in the Legislature in 1871, by the Premier, Mr. John Sandfield Macdonald, providing for the establishment of a College of Technology for teaching mathematics, chemistry, modern languages, civil and mechanical engineering, and drawing.

The bill was strongly opposed in the House on the ground that its objects would be better met by giving additional aid to the Provincial University; but in the end it was carried and a grant of $50,000 made for the purpose of equipping a building for carrying out the plans. The building at the corner of Church and Adelaide streets, then occupied by the Mechanics' Institute, afterwards the Public Library, was purchased by the Government and fitted with the necessary laboratories, lecture rooms and drafting rooms. It was intended to combine the English and American systems of technical education by teaching regular



W. H. Ellis

students in engineering and chemistry during the day, and giving lectures to working men in the evening. Just before the new building was ready for occupation, the Sandfield Macdonald Government was defeated on another issue, and Mr. Alexander Mackenzie was called upon to form a new cabinet.

The members of this Government had, before they came into power, strongly apposed the scheme, which was now left to them as a legacy by their predecessors; and they did not carry it out without important modifications.

At first only the evening classes were organized. To conduct these Mr. James Loudon, afterwards President of the University, Mr. Wm. Armstrong, C.E., and the writer were appointed instructors. The classes, particularly Mr. Armstrong's classes in drawing, were largely attended.

The year 1877 marked the beginning of a new stage in the development of the young institution. In that year the Hon. Adam Crooks, Minister of Education, with the approval of the Lieutenant-Governor in Council, changed the name from "College of Technology" to "School of Practical Science," and recommended the erection of a building in the University grounds for the accommodation not only of the students of the School, but also for the science teaching of University College so that the School and the College might mutually help each other. This plan was devised by the Minister with the advice and assistance of the Hon. Mr. Justice Thomas Moss, Vice-Chancellor of the University, Dr. (afterwards Sir Daniel) Wilson and Professor James Loudon.

In accordance with this plan, the north wing (just condemned as unsafe) of the present Engineering Building, was erected; and it was opened on the 1st of October, 1878. This building contained a chemical laboratory under the charge of Professor Croft to whom the present writer was assistant. The chemical laboratories were in the rooms just vacated by Mr. Anderson and Professor Wright and all the chemical teaching of University College and of the School was carried out there and in the lecture room in connection with them.

The basement was occupied by Professor Chapman as an assay laboratory. There was another lecture room on the first floor and a drafting room (at the east end). This constituted the quarters of the Engineering Department and was under the charge of Professor Galbraith. The floor above was devoted to the Department of Biology and was presided over by Professor Ramsay Wright. Professor Loudon had a room on the ground floor, but all his teaching was done in the round tower at the west of the main building.

Professor Croft was Chairman of the Board and Professor Ramsay Wright secretary. The whole of the engineering teaching, including the drawing, was done by Professor Galbraith.

In those days the School of Practical Science was in fact, though not in name, an integral part of the University. It was supported by annual grant of the Legislature, not out of the University endowment; and it was not under the control of the Senate; but the students received instruction side by side with the students of University College, from the same professors; and it was governed by a Board of whose seven members, five, including the chairman and secretary, were professors in University College.

In 1889 there was another change. The University Federation Act was passed in 1887 establishing a University Teaching Faculty, and removing the professors of chemistry, physics, mineralogy and geology, and biology from University College to the Teaching Faculty of the University. This severed the connection between the School and University College. In October, 1889, the School of Practical Science was affiliated to the University of Toronto and in November of the same year Professor Galbraith was appointed principal and the management of the School was "entrusted to a Council composed of the Professors, Lecturers and Demonstrators appointed on the Teaching Faculty of the School."

The first Council was composed of: Principal Galbraith, Professor of Engineering, Chairman; W. H. Ellis, Professor of Applied Chemistry; L. B. Stewart, Lecturer on Surveying, Secretary; C. H. C. Wright, Lecturer on Architecture; and T. R. Rosebrugh, Demonstrator in the Engineering Laboratory.

The University Departments of Biology, Mineralogy and Geology, and Chemistry were now removed from the School to quarters of their own.

The next step forward was the enlargement of the Engineering Building and the equipment of the engineering and metallurgical laboratories.

The diploma of the School of Practical Science was at first given only in Civil and Mechanical Engineering and Analytical and Applied Chemistry. Subsequently Mining Engineering and Architecture were added.

In 1892 a fourth year of instruction was added to the three required for the diploma, at the end of which the student might obtain the degree of B.A. Sc. In 1900 the Senate of the University passed a statute adopting the School of Practical Science as the Faculty of Applied Science of the University of Toronto. In 1901, the Chemistry and Mining Building was begun and relief given for the time to the overcrowded condition of the laboratories and drafting rooms which had become serious.

On the 3rd of October, 1905, a Royal Commission was appointed to enquire into and report upon a scheme for the management and government of the University of Toronto and University College. The advisability of the incorporation of the School of Practical Science with the University of Toronto; and certain other subjects. In April, 1906, the Commission reported, recommending, among other things, as follows:—

1. The powers of the Crown in respect to the control and

management of the University, should be vested in a Board of Governors chosen by the Lieutenant-Governor-in-Council.

2. The Senate should direct the academic interests of the University.

3. The School of Practical Science should be united with the University as its Faculty of Applied Science and Engineering.

On the 14th of May of the same year, the Legislature passed the University Act carrying out the recommendations of the Commission, clause 6 of which reads:

The School of Practical Science is hereby united with and shall form part of the University and constitutes the Faculty of Applied Science and Engineering thereof.

On the 15th day of the following June this Act went into force and with that the School of Practical Science became de jure what it had always been de facto—the Faculty of Applied Science and Engineering of the University of Toronto.

HISTORY OF THE APPLIED SCIENCE BUILDINGS.

C. H. C. WRIGHT, B.A. Sc.

In order to furnish accommodation for the teaching of engineering, in accordance with the proposition of the Hon. Adam Crooks, the north wing of the present Engineering Building was erected in 1877-78, and called the School of Practical Science. This building was heated with hot air and the furnaces together with their flue and supply of coal occupied a large portion of the basement. In the western portion, however, there were situated the mineralogical and assaying laboratories, over which Professor E. J. Chapman presided. The ground floor was occupied by Professor H. H. Croft and his students in chemistry. The western wing of the first floor was also devoted to chemistry, while the remaining five small rooms in the centre and eastern wing were devoted to engineering, and here Professor J. Galbraith with his small class started work in 1878. In the attic the department of biology was presided over by Professor R. Ramsay Wright. Thus, this small building housed the departments of mineralogy, geology, chemistry, engineering and biology, and in it were trained side by side students in Arts, Medicine and Engineering.

In order that the Province of Ontario might keep pace with other countries in the education of the engineer, it was decided in 1888, to establish engineering laboratories in connection with the S.P.S., in which might be studied those important problems in strength of materials, hydraulics, thermodynamics and electricity, which were occupying the attention of the engineering world. This rendered necessary extensive equipment as well as considerable building accommodation.

For this purpose, the construction of the central portion and southern wing of the present Engineering Building was undertaken immediately. This addition was completed and first occupied in the fall of 1890. In the spring of this same year the eastern portion of the Main Building of the University, in which was situated the library, was destroyed by fire, and until the new library building was erected, the library was provided for on the top floor of the central portion of the S. P. S. Reading room accommodation was obtained by building an extra story over the eastern and western parts of the present north wing of the School.

C. H. C. Wright, B.A. Sc.

Gradually, by the erection of new buildings, the Arts departments were removed, until in 1894, the S.P.S. was devoted entirely to the work of the School. The Chemistry and Mining Building, facing College Street, was completed in 1905, and provided accommodation for the departments of chemistry, mining, mineralogy and geology of the School, and for those of mineralogy and geology of the University. Immediately to the north of the Chemistry and Mining Building was erected about the same time the Milling Building, for the accommodation of that branch of Mining. In the fall of 1901, a small observatory was built for the department of Astronomy of the S.P.S. This building was replaced by the larger one now in use, which provided in addition to the observation room, a small calculating room. It is hoped that by October, 1909, the new building to the east of the Main Building of the University will be completed and occupied by this department.

At present there is under construction to the south of the Engineering Building a laboratory for thermodynamics and hydraulics, which promises to be ready for the work of the coming session, 1909-10, and will provide excellent facilities for the advancement of this very important branch of engineering education. In addition, it will also offer opportunities for research work along these lines.

For the past two sessions the Second Year draughting has been accommodated in the Examination Hall of the University, and during the present session, the Third Year draughting in the departments of Civil and Mining Engineering has been accommodated in the Physics Building.

It is apparent to anyone who has studied even casually the progress of engineering education, that thirty years ago the demands for building accommodation were very few:— a lecture room together with a draughting room for the engineering side of the work; a lecture room for mathematics, and space for a little chemistry and physics, was all that was deemed necessary. However, as the benefits of education suitable for the different divisions of engineering, civil, mining, mechanical and electrical, became apparent to the world, the demands for laboratory accommodation have increased very rapidly. In addition to the increase in accommodation required for improvements in the educational requirements, must be considered that due to the increased numbers of students taking these courses; and, if the University of Toronto and the Province of Ontario wish to maintain the good name won by the School of Practical Science, they must be prepared to provide large additions in building and equipment in the immediate future. Situated as Toronto is in the centre of the clay industries (the largest industries of the Province) something should be done for Ceramics. Electrical engineering demands the lower floors of a large building, and at the same time, the requirements for the study of the strength and properties of building materials, including cement and reinforced concrete, must not be neglected.

President Falconer, writing on "The Needs of the University of Toronto" in the pages of "The University Monthly," says: "The University has within a short time become one of the larg-" est in the British Empire and stands in the front rank on this " continent." . . . . "During the last two years, not in-" cluding the present, the ratio of increase in the Faculty of Ap-" plied Science has been thirty-two per cent., a larger proportion-" ate increase than in any other Faculty." . . . "The most " urgent pressure for accommodation during the past winter, " apart from the necessity for schools for the Faculty of Educa-" tion, was in the Faculty of Applied Science. This Faculty is " housed in the old Engineering Building built for the School of " Practical Science, and in the new Science building facing on " College Street, commonly known as the Chemistry and Mining " Building. These buildings are not sufficient for the needs of " this Faculty."

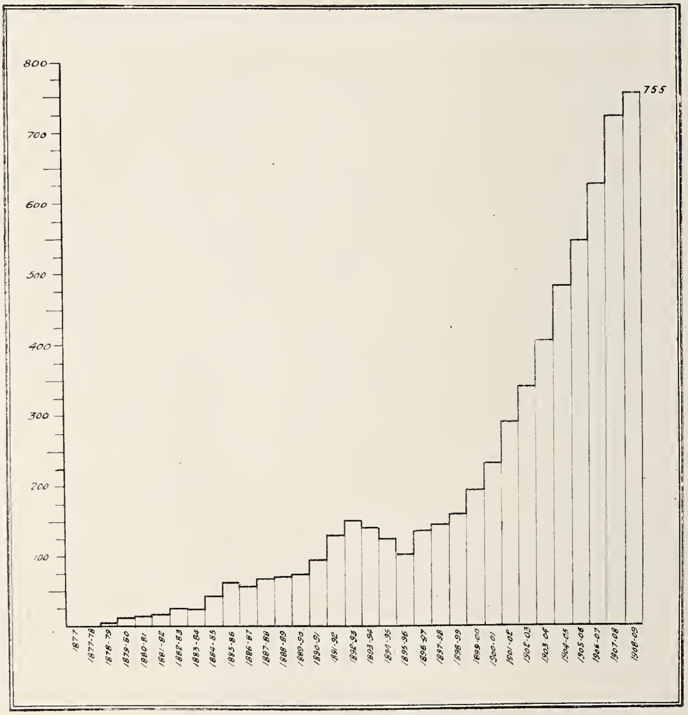


Diagram Showing the Growth in Attendance

THE NEEDS OF THE FACULTY OF APPLIED SCIENCE.*

PRESIDENT R. A. FALCONER

Unless all omens fail the Faculty of Applied Science will soon become the second in size in the University, and may creep up upon the Faculty of Arts, though Arts has such a lead that it will probably hold the first place for many years. During the last two years, not including the present, the ratio of increase in the Faculty of Applied Science has been thirty-two per cent., a larger proportionate increase than in any other Faculty. It is also worth mention that a much larger proportion of the students of this Faculty than of those in the Faculty of Medicine come from the city of Toronto. About a third of the whole number have their homes in this city, the reasons for which may not be very difficult to discover.

This Faculty has developed healthfully and in conformity with the demands of the country. Ontario has become a great manufacturing province without at the same time ceasing to develop its agriculture. The Agricultural College at Guelph is a splendid evidence of the good hope that lies before our farming population. For the other side of our life we also need leaders—in opening up new country by railways, in constructing large works, in developing mines. For producing men who will direct these activities there is the Faculty of Applied Science, formerly known as the School of Practical Science.

A distinction must be kept clearly in mind. The aim of the Faculty of Applied Science is not to be confounded, as is sometimes done, with the work of technical education. The latter consists on the one hand of giving artisans and the youth in school instruction in the scientific principles that underlie the various trades in which they may be engaged, and on the other hand of instruction in the principles and technique of the actual trades. Technical education is meant for the man who, whether as foreman or skilled workman, is engaged in some trade. And a highly honorable function does this man perform for the commonwealth. More and more demand arises for a supply of such intelligent, well-trained, capable men who take pride in their trade. Those men who are seeking to direct the attention of the public to the necessity of providing this technical education are engaged in a good work.

In the Faculty of Applied Science, however, students are being trained who will become the directors of the works in which the technically trained men will be employed. They should be trained men of the manifold industrial activities of the

---

* This is one of a series of articles on "The Needs of the Univerity of Toronto," contributed to the *University Monthly* by President Falconer.

Robt. A. Falconer.

country. As workmen they may perhaps be actually unskilled, but they must know how the work should be done, and be able to detect its worth and appraise its value.

The complexity of our industrial life, the variety which is daily increasing, and the rapid expansion of our population, as well as the rise in the scale of comfort, will not only bring more students into this Faculty, but will occasion additions to the departments taught within the Faculty. At once the question arises, is there to be no limit to this development? Are we to keep on adding new departments indefinitely? We have not as yet gone far beyond the ordinary branches, the object of the Faculty having been to lay deeply and well the principles of science by means of concrete applications of these principles in the few leading departments into which most students turn. There are at present the departments of Civil Engineering, Mining Engineering, Mechanical and Electrical Engineering, Architecture, Analytical and Applied Chemistry and Chemical Engineering. As has already been remarked, these have been established to meet the requirements of the life of the Province. The relative numbers in attendance in the past may very probably change in the future, as for example in mining, as Ontario becomes increasingly a mining province.

In connection with this Faculty there is the pressing need of more room. One of the best objective evidences of its growth is shown by looking at the northern part of the old Engineering building which was erected in 1878 for the school of Practical Science, and then turning to the buildings now used by this Faculty. This old building has been greatly enlarged but has been long filled. Then came the new building on College Street, one of the best in the whole group on the University grounds. In the old building there are the departments of Electrical Engineering, Strength of Materials, Surveying, Drafting, Physics and Architecture, and at present also Thermodynamics and Hydraulics. In the new building are Chemistry, Electro-chemistry, Geology, Mineralogy and most of the lecture-rooms used by this Faculty. In its eastern wing is the valuable palaeontological museum. The mining department is housed in a building in the rear.

Last year the plans of the Convocation Hall were further enlarged by the erection in the rear of the large hall. It is used for examinations and also for drafting. So far the Drafting has been confined to the students of the second year. A large amount of space is required for this department inasmuch as the policy of the Faculty has been to give each student a desk at which he is supposed to spend all the time that he is not at lectures or in some laboratory. Drafting thus occupies a very large share of his attention. Hitherto each student has had his own desk, and unless it should be found possible in some of the work to have two students at one desk, there must be an increased space devoted to Drafting.

Until the new building for Thermodynamics and Hydraulics was under way it was impossible to draw up a four years' course in this Faculty. The structure is to be ready for occupation by the autumn and with its equipment will provide ample opportunity for this important side of Engineering. The removal of the Thermodynamic department from its present extremely congested quarters will allow for some expansion of the departments of Electrical Engineering and Strength of Materials, though if the increase of students continue this cannot be much more than a makeshift for a short time. According to the plans of the architect a handsomely designed addition to the new Thermodynamics and Hydraulics laboratory facing on the main entrance to the University from College Street will serve both to adorn the approach and to provide some much needed accommodation until part or all of the old Engineering building can be replaced by a new structure.

In a Faculty where so much of the instruction must be given in laboratories equipped with expensive apparatus or machinery it is necessary to spend money on buildings. And most of these buildings hitherto erected have been devoted to departments already taught in the Faculty. But, as has been stated, new departments must be originated. With the development of the mines of Northern Ontario an immense impetus has been given to this side of industrial life. Fortunately our mining equipment is good, and under the direction of Professor Haultain, who has had a thorough experience in mining, we may reasonably expect that the University of Toronto will have a large share in training those who are to develop the immense mineral resources of the Province. Closely akin to Mining is Metallurgy. There is metallurgy of gold and silver, but more important for a Province with large manufactures is the metallurgy of iron and steel. It cannot be long until the instruction now given in this subject will be greatly increased. Other departments in which extension may be demanded within a short period are Architecture and Applied Chemistry. Already the architects have approached the University with the object of getting additions made to the department in the way of practical design. In Applied Chemistry there will come developments in the application of chemical science industrially. Even if we do not adopt the policy of attempting to provide for every branch of Engineering education, we must at least prepare men for launching and guiding those industrial activities which are most adapted to the natural resources of this Province. All development of this kind is expensive, both for the undergraduate and the graduate student.

In considering the necessary additions to the staff occasioned both by the rapid increase of the students and of the subjects to be taught, it is necessary to bear in mind that men fitted to develop important departments of the Faculty of Applied Science are able to earn good incomes at present, and that there are also many opening for young men of ability which will bring them in much more within a few years than they would earn in the University in the same time. And yet it is of immense importance for us to have men who have some training of a practical character besides their academic equipment. Their experience is extremely valuable in giving them selective faculty and power of adjustment of theory to practical necessities. This has to be taken into account when any addition to the staff or department is contemplated. While a few men will be content with a small salary in a university faculty because the position is supposed to be secure and free from many of the difficulties of a practical engineer's life, many of the brightest and most energetic minds are drawn to the active exercise of their profession. Some men of this sort are required in a faculty; and the salary is a factor that cannot be neglected.

THE ENGINEERING SOCIETY OF THE UNIVERSITY OF TORONTO

T. H. HOGG, B.A.Sc.

The Engineering Society of the Faculty of Applied Science and Engineering of the University of Toronto was founded in 1885, being known at that time as the Engineering Society of the School of Practical Science. The names most intimately connected with its beginning are Messrs. Herbert Bowman and T. Kennard Thomson, who were undergraduates at that time. It is essentially a student's society and only graduates and undergraduates in Engineering of the University are admitted as ordinary members.

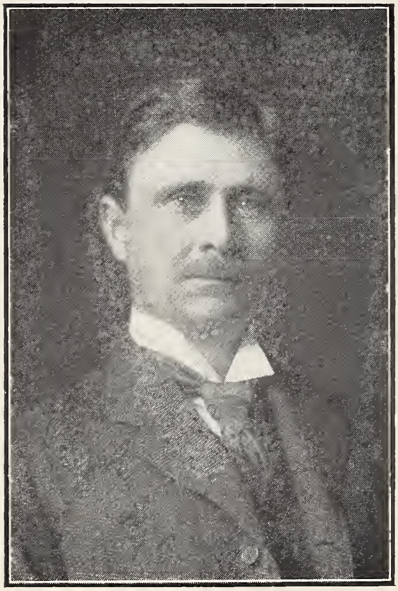
The objects of the Society according to the Constitution are:

1. The encouraging of original research in the Science of Engineering.
2. The preservation of the results of such research.
3. The dissemination of these results among its members.
4. The cultivation of a spirit of mutual assistance among the members in the practise of the profession of Engineering.

The membership of the Society has risen steadily in point of numbers since its inception. It began with a total membership of about thirty. At the present time of ordinary members there are 750 with a life membership of about the same, making a total of nearly 1,500.

For the first few years of its existence, membership for the undergraduates was optional, but recently through the co-operation of Dean Galbraith, it has been made compulsory for all in attendance in the Faculty, a fee of $1 per year being imposed and collected with the regular tuition fees.

Until the fall of 1908 meetings were held each alternate week of the academic year: that is from October until April. The Executive Committee then decided that the time had come for a division of the Society, as the meetings were becoming too large and unwieldy, for good discussions of the papers presented. The constitution, too, had become inadequate, not having been revised since the founding of the Society. A new constitution was therefore drafted and in this provision was made for sectional meetings, the members being grouped according to the courses taken, the Civils and Architects, Mechanicals and Electricals, and Miners and Chemists forming three divisions. These smaller meetings are held alternate to the general meetings, and at them papers of more specialized interest are read. By this means a much freer discussion is obtained and many more of the undergraduates are enabled to prepare papers and deliver them. These smaller meetings are presided over by the vice-presidents of the respective sections, and no business of a nature affecting the Society as a whole is transacted. The general meetings are reserved for business and for topics of general interest to the student body. As a natural outcome the papers given at the sectional meetings are nearly all by undergraduates while those given at the general meetings are by graduates and men prominent in the outside world.



H. E. T. Haultain
First Student President of Society

R. J. Marshall
Present President of Society

The appointment of a permanent secretary in the fall of 1908 marks a turning point in the affairs of the Society. For a number of years, certain supplies had been handled for the students, the revenue accruing from the sale of these being used for the expenses of carrying the Society along. This branch became so large that it was found necessary to appoint a secretary who would devote his time to the ordering and sale of supplies, and the other work incidental to the organization. The Society now handles, at a slight increase in cost, all draughting supplies, etc., used in the Faculty, thus affording a great reduction over the old prices.

In its infancy the question of funds was a serious one with the Society, but happily that worry is now over. Each undergraduate in the Faculty pays an annual fee of $1. This, with the income from the sale of supplies makes a sum which allows of the handling of many departments of advantage to the students and to the Faculty in general. Probably the most important of these departments is the publication of the Society monthly, "Applied Science." Before saying more of this, we must trace its development. In the early days of the Society the transactions, containing the papers read at the meetings, were issued yearly. The first volume of the Transactions was published in 1886, and was a pamphlet of 43 pages. In the then financial condition of the body this was a serious undertaking, as about 500 copies were issued. A gradual increase in membership together with a great development in enthusiasm caused the sending out in 1895, of advance proofs of the papers read, for discussion. This was too much of a forward step and in consequence the Society was nearly swamped. Eventually it recovered its lost ground and from that time until 1906 there was a continuous development in the size of the pamphlet. The No. 20 issued in 1906-1907 had about 250 pages and was very fully illustrated.

With the division of the Society into sections and the increased number of papers forthcoming on that account, it was decided to change the publication to a monthly. This was done in 1907, and the monthly, "Applied Science," was enthusiastically received by all the graduates.

At the present time "Applied Science" is a thoroughly progressive and up-to-date periodical, not of interest merely to graduates of the Faculty nor courting inspection as an academic journal, but resting on its merits as an engineering magazine. It has to-day a circulation of 1,700 copies. There are exchanges with all engineering societies and periodicals in the United States and Canada. The articles appearing in it have been copied in nearly all the leading engineering publications. "Applied Science" in its short life has done much towards cementing together the graduate feeling, and according the Faculty the recognition among engineers and the general public which it deserves.

As the organ of the Engineering Society, and as an outward manifestation of what the Society is, the monthly has well justified its existence.

As the membership increases and each year of added tradition puts new enthusiasm into the work of the Society, one looks back on a connection with the Society with pride, and a feeling arises that, with the strong cohesion and power of initiative exhibited by its executive committees in the past, there must certainly be a broad field of action for the Society in the future. While it is true that its work is mainly carried on by students, still not all of its benefits are conferred on its members alone, and we hope in the future that the Engineering Society with its strong, compact organization, will do much towards procuring for engineers the recognition from the general public which they deserve.

ADDRESS—DEAN GALBRAITH.[*]

Gentlemen, — Custom in this Society demands of the retiring president, whether wisely or otherwise it is not for me to say, an address at the close of his term of office. Fortunately for him no by-law exists governing either the form or matter of his essay. He is not required to confine himself to the third person and has all the freedom implied in the declaration, printed in every volume of the "Transactions," that "the Society will not hold itself responsible for any statements or opinions which may be advanced in the following pages." Answerable thus to no one and confined only by my natural limitations, I jotted down from time to time, by way of gathering material, ideas as they occurred to me. When a sufficient number had accumulated to enable me to form a judgment of their suitability for the purpose in view, I was dismayed to find that my stock was shopworn and that it would not be an easy task to work it into presentable shape. However, it was then too late to throw it away. After a period of severe reflection I convinced myself that it might be of some value to the younger members of the profession and that even the seniors might be interested in the viewpoint of an engineering teacher, differing as it does in many respects from their own. I decided, therefore, to form my material into a paper under the somewhat hackneyed title of "The Engineer and His Work."

In tracing backwards the history of the engineer to classical times, two words stand out with marked prominence— *μηχανή* and *ingenium*. The root idea of the former is contrivance, resource, ways and means; of the latter, nature, intelligence, ingenuity. The phrase "mechanical genius" describes the highest attribute of the engineer, the control of mind over matter, the power of bending the forces of nature to the use and convenience of man. The antiquity of the words and the continued application of their derivatives down to the present day to the same set of ideas are evidence that the art and craft of the engineer are not of yesterday nor the outcome of modern conditions. The remains of the great structures of ancient civilizations — temples and amphitheatres, baths, aqueducts and sewers, walled cities and military roads, are witnesses to the genius of engineers whose names have been long forgotten, of men skilled in surveying, levelling, drawing, hydraulics, excavation and construction. The entrenched camp, the tunnelled approach, the battering-ram, catapult and moving tower were the devices of the engineer. He had a great part then as now in the arts of peace and war.

---

[*] Address by Dean Galbraith, Retiring President of the Canadian Society of Civil Engineers, delivered at the annual meeting of the Society in Toronto, January 27th, 1909. Printed with the permission of the Council.

An inscription on a marble altar discovered in 1866 near Lambaese, Algeria, of date A. D. 152, contains a petition from Varius Clem-

J. Galbraith, M.A., LL.D.

ens, governor of Mauritania, to Valerius Etruscus, governor of Numidia. It reads as follows:

"Varius Clemens greets Valerius Etruscus and begs him in his own name and in the name of the township of Saldae to despatch at once the hydraulic engineer of the Third Legion Nonius Datus with orders that he finish the work which he seems to have forgotten." The petition was favorably received by the governor and by the engineer Nonius Datus, who when he had fulfilled his mission wrote to the magistrates of Saldae the following report:

"After leaving my quarters I met with the brigands on my way, who robbed me even of my clothes and wounded me severely. I succeeded after the encounter in reaching Saldae where I was met by the governor, who after allowing me some rest took me to the tunnel. There I found everybody sad and despondent; they had given up all hopes that the two opposite sections of the tunnel would meet, because each section had already been excavated beyond the middle of the mountain and the junction had not yet been effected. As always happens in these cases, the fault was attributed to the engineer, as though he had not taken all precautions to ensure the success of the work. What could I have done better? I began by surveying and taking the levels of the mountain; I marked most carefully the axis of the tunnel across the ridge; I drew plans and sections of the whole work, which plans I handed over to Petronius Celer, then governor of Mauritania; and to take extra precaution I summoned the contractor and his workmen and began the excavation in their presence with the help of two gangs of experienced veterans, namely a detachment of marine infantry and a detachment of Alpine troops. What more could I have done? Well, during the four years I was absent at Lambaese expecting every day to hear the good tidings of the arrival of the waters at Saldae, the contractor and the assistant had committed blunder upon blunder; in each section of the tunnel they had diverged from the straight line, each towards his right; had I waited a little longer before coming, Saldae would have possessed two tunnels instead of one."

Nonius Datus, having discovered the mistake, caused the two diverging arms to be united by a transverse tunnel; the waters of the Ain-seur could finally cross the mountain and their arrival at Saldae was celebrated with extraordinary rejoicings in the presence of the governor, Varius Clemens, and of the engineer. (Lanciani—Ancient Rome in the Light of Modern Discoveries.) We can, I am sure, sympathize with our confrere the engineer of the Third Legion in his difficulties, and rejoice with him in his triumph.

The Romans as a rule constructed their aqueducts with grades approaching those of our modern railways. They tunneled mountains and bridged valleys, not, it must be remembered, that they were ignorant of the fact that water could be carried across valleys in inverted siphons, but because they were unacquainted with the use of cast iron. There is at least one instance of a masonry or perhaps a concrete pipe constructed by the Romans which was able to withstand pressures as high as ten atmospheres.

The first advance in engineering after the time of the Romans was due to the invention of gunpowder in the beginning of the fourteenth century, or perhaps it may be more correct to say, to its introduction into Europe about that time. By it the methods of excavation and of attack and defence were revolutionized.

The next great step was the introduction of iron as a structural material, which was rendered possible by the use of coke as a blast furnace fuel in the early part of the eighteenth century. Following the manufacture of coke iron came Watt's epoch-making improvements in the steam engine in the latter part of the same century—the separate condenser, expansive action, the double acting cylinder, the steam jacket, the parallel motion, the throttle valve, the governor, the water gauge, the indicator, and many others. Watt also conceived and patented in 1782 the idea of the compound engine, which he thus described: "A new compound engine or method of connecting together the cylinders and condensers of two or more distinct engines so as to make the steam which has been employed to press on the piston of the first act expansively on the piston of the second, etc." Watt, in fact, gave the world the steam engine which exists to-day, the improvements made since his time being as nothing compared with his. The achievements and personality of James Watt cannot be better described than in the words of Sir Walter Scott after meeting him in 1818:

"There were assembled about half a score of our Northern Lights. . . . Amidst this company stood Mr. Watt, the man whose genius discovered the means of multiplying our national resources to a degree perhaps even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the summit of the earth—giving the feeble arm of man the momentum of an Afrite—commanding manufactures to arise as the rod of the prophet produced water in the desert—affording the means of dispensing with that time and tide which wait for no man and of sailing without that wind which defied the commands and threats of Xerxes himself.

This potent commander of the elements, this abridger of time and space—this magician whose cloudy machinery has produced a change on the world, the effects of which, extraordinary as they are, are perhaps only now beginning to be felt, was not only the most profound man of science, the most successful combiner of powers and calculator of numbers as adapted to practical purposes—was not only one of the most generally well-informed, but one of the best and kindest of human beings.

There he stood, surrounded by the little band I have mentioned of northern literati, men not less tenacious generally speaking of their own fame and their own opinions than the national regiments are supposed to be jealous of the high character they have won upon service. Methinks I yet see and hear what I shall never see or hear again. In his eighty-second year the alert, kind, benevolent old man had his attention alive to every one's question, his information at every one's command. His talents and fancy overflowed on every subject. One gentleman was a deep philologist—he talked with him on the origin of the alphabet as if he had been coeval with Cadmus—another a celebrated critic—you would have said the old man had studied political economy and belles-lettres all his life—of science it is unnecessary to speak, it was his own distinguished walk. And yet, Captain Clutterbuck, when he spoke with your countryman, Jedediah Cleishbotham, you would have sworn he had been coeval with Claver'se and Burley with the persecutors and persecuted, and could number every shot the dragoons had fired at the fugitive Covenanters. In fact we discovered that no novel of the least celebrity escaped his perusal, and that the gifted man of science was as much addicted to the productions of your native country, in other words as shameless and obstinate a peruser of novels as if he had been a very miller's apprentice of eighteen."

One scarcely knows which to wonder at most, the genius of the engineer or the vision of the poet.

Sir Humphrey Davy said of Watt: "He was equally distinguished as a natural philosopher and a chemist and his inventions demonstrate his profound knowledge of these sciences."—(Muirhead's Life of James Watt.)

Watt was not only the greatest of mechanical engineers—he was an expert surveyor and civil engineer as well. He spent several years of his life in making surveys and reports on harbors, docks, canals, water works, bridges, etc. He invented a quadrant, a surveyor's micrometer, clock, and other instruments of precision. As an illustration of the rate of pay of civil engineers in 1770, Watt's charge for the survey of the Strathmore Canal may be of interest. The field work covered 43 days for which he charged £80 including travelling and living expenses; for the preparation of the report he was paid the further sum of £30.

The manufacture of iron on the large scale has been accompanied within the last thirty years by an enormous expansion in the manufacture of Portland cement and the consequent return to the use of concrete as a structural material. Within the same period the development of the dynamo has marked another advance comparable in importance only with that of the steam engine. It is not to be supposed, however, that these modern features have entirely absorbed the energies of the engineering and industrial world. Few of the ancient arts and manufactures have lost their importance. They have undergone development and transformation under the light of modern science and the stimulus of modern conditions. Through all these changes man, their author, seems to survive almost unchanged. The human race, civilized or savage, is, man for man, very much the same as it was three thousand years ago. Nonius Datus had the full qualifications for admission into the Canadian Society of Civil Engineers. No one would recognize any essential difference between him and other members, except perhaps that he was better educated, being able to talk Latin.

It will be unnecessary to recite to an audience of engineers in any minute detail the various fields of activity now open to the profession. It may be useful, however, to attempt a classification of the functions of the engineer irrespective of the special branch in which he may be engaged. They may be roughly analyzed as follows:

1. Design—the preparation of the drawings, specifications and estimates of cost for works not yet in existence—the study of the problem, the devising of ways and means—in short, the consideration of all questions affecting the construction and efficiency of the contemplated work.
2. Survey and inspection—making the examination of existing works or ground for the purpose of determining necessary extensions and changes—laying out new work—measuring work done—inspection of materials and workmanship, and generally, the superintendence of construction.
3. Superintendence of the operation and maintenance of works in running condition.
4. Determining and estimating costs of various kinds.
5. Reporting upon various physical and financial features of existing or proposed works.

To successfully perform these functions the engineer must have knowledge, training, experience, judgment, resourcefulness, business capacity and ability to deal with men, in fact the qualifications which are necessary for success in any line of life. It goes without saying that he should be an educated man in the best sense of the term. It has sometimes been said that the engineer should be forty per cent. engineer and sixty per cent. man; one might better say that he should be one hundred per cent. engineer and one hundred per cent. man, the terms engineer and man not being, it is to be hoped, mutually exclusive. It is necessary that he should have a thorough grasp of the objects and methods of the promoters and proprietors of the works on which he is engaged and be quick to discern where expense may be saved, keeping the necessary efficiency in view. It is not requisite that he be an expert mathematician, chemist, physicist, geologist, biologist, metallurgist, mechanic, accountant, lawyer or political economist, but it is desirable that he be an expert engineer. For this purpose he should have a sound acquaintance with the principles and possibilities of various branches of specialized knowledge in so far as they bear upon his own work.

In other words, he should have a clear perception of how and how much these branches may aid him in his own problems and be able to determine at any time to whom he should go when his own knowledge is insufficient. He must know the limitations of his own profession and therefore should know something of the fields which surround his own. Often it happens that some particular fence has almost disappeared and it becomes difficult to determine where the engineer ends and the neighboring proprietor begins. Indeed, it may be said that the fences are continually changing so that the engineer never can hope to be in the position of not requiring to study non-engineering things. The training to be given in the engineering schools should deal more with subjects which are not engineering than with those which are, the reason being that the time for such training is short whereas that to be devoted to engineering is long. Above all, the curriculum should be educative, the student should be trained in clear thinking and in clear expression. When he graduates he should have acquired a sufficient knowledge of his geography to have some idea of where he is in the world in general and in the engineering world in particular. It is now recognized that the study of the applied sciences has all the educational advantages usually attributed to that of the pure sciences. They involve the same principles, exercise the same faculties and produce the same educational results as the pure sciences. The fact that their objects are wholly economic does not detract from their educational value but provides an additional stimulus to scientific effort. The term "applied science," at one time suitable, is now rather misleading in connection with the science taught in the engineering schools. It suggests the idea that the business of the teachers in these schools is to train their students in the application to practical purposes of pure science. This is far from being the truth. The necessities of the practical world have developed great bodies of science with which the investigators in pure science are more or less unacquainted and are unable to take part in, either in the way of investigation or teaching, on account of the natural limitations of time, opportunity and taste. The term "practical" better described the engineering and technical sciences and the term "applied" should be discontinued in this connection. The practical sciences are taught in the engineering schools and are applied by the engineer in his work. The teachers of practical science should keep in touch with the requirements of engineers and manufacturers and not develop merely into laboratory investigators following their own lines of thought, indifferent to where these may lead. This is right and proper in the region of pure science, but those engaged in practical science must deny themselves the pleasures of unrestricted freedom. They cannot afford to soar too long in the clouds but must return again and again to earth. They must never forget that their only reason for being is the assistance they give as educators or investigators to the actual workers in the industrial fields. It is essential for the success of their work that they should be officially independent of the teachers in pure science in the university organization. They should have experience in engineering work, not for the purpose of teaching it, for there is little engineering which can be profitably taught in a school, but in order that they may be able to properly direct their true work, the teaching and investigation of practical science.

The engineer is not simply an applier of the sciences. He comes into contact with men as well as with things. He should understand the principles underlying commerce and finance, company organization, cost keeping and accounts. A financial statement ought not to be a mystery to him nor a railway report past understanding. He should have, at least, as clear a conception of the meaning of a contract as the lawyer who drafted it. He should be able to write a report in clear and expressive English. The engineering schools are beginning to understand that these subjects are not altogether above and beyond them, nor yet beneath them. It is true that an expert business man cannot be trained in a school; no more can an expert engineer. Business science, however, can be taught just as successfully as chemistry or physics. Business men are said to have a prejudice against academic training in business. Engineers once had a similar prejudice against engineering schools. With a better understanding of their field on the part of the schools will come a better appreciation on the part of the business man. The schools should devote their energies to the teaching of principles. The teaching of practical methods should be chiefly for the purpose of making the connection between theory and practice, thus clarifying and impressing the principles on the student's mind.

One of the most difficult subjects in the curriculum is English. It should not be taught as are French and German for the purpose of giving the student access to its literature, engineering or otherwise. Students can, as a rule, get the information they want from English books without the aid of a professor of English. The object in teaching English in the engineering school should not be to give the student a grasp of the principles underlying the formation of words and sentences. It should be assumed that his high school training in grammar is sufficient for this purpose. The instruction most necessary under present conditions is training in the use of the language. However, there may be a better way. There does not seem to be any good reason why the course of instruction in English in this country should not be turned end for end. Why should not the secondary school teach the boy to use his mother tongue and the university teach grammar?

One of the dangers to be avoided in the academic course of the engineer is over-specialization. It should be remembered that the graduate does not always find work in the branch to which he has devoted his four years of academic life. If his course, therefore, has not included a reasonable number of subjects more or less common to all branches of engineering he will have good cause of complaint against the educational authorities. A properly educated graduate ought to be able by his own reading to adapt himself to any situation wherein he may be placed. A broad education is the best preparation for specialization in after life.

The academic requirements for young men entering the profession would be better determined by the discussions of practising engineers than of any other body of men, and yet they seem to have little or nothing to say on the subject. There seems to be something in the work of the engineer which suppresses talk, even useful talk. This is very well in a way but may be carried too far. Engineers ought not to hide their light under a bushel and expect the world to reward them for their silent work's sake. The world is too busy a man to study engineering and would perhaps take more interest in engineers if they were to take the trouble to explain things. However, this disability is probably on the decrease owing to the influence of the engineering schools; and engineers are not as silent as they once were. They show signs of awakening and will not long be content to act simply as advisers or scientific hired men, indifferent to the big world as long as they get their pay. The engineer of the future will force his ideas of engineering education on the public and force them more effectively than his predecessors of the past and present.

The engineer should have a thorough knowledge of the materials with which he has to deal. The laboratory investigations of the chemist, the physicist and the biologist have added greatly to the store of knowledge at his disposal. Laboratory results, however, often require modification in as much as the artificial conditions surrounding them may differ essentially from the conditions of practical work. Thus it is not sufficient to accept materials of construction simply because they have passed the specified short time tests. The engineer should know in addition as much as possible of the history of his materials, their sources, methods of manufacture, modes of growth, etc.; without this knowledge the rapid examinations in the laboratory and testing room may altogether fail in their purpose of excluding unsuitable materials. Similarly in construction, it is not sufficient to examine the completed work and see that it complies with certain specified final conditions. It is necessary to watch the whole process of manufacture and construction from the beginning to the end. In other words, no short time tests or inspection will relieve the engineer from the necessity of knowing the whole history of his materials and construction. It is this fact which has forced on the profession what one may call standardized materials and methods of construction developed from experience. New materials and new processes are wisely looked upon with distrust and can achieve success only after a long period of trial. The life of a structure or machine is not only shortened by imperfections of material and workmanship and the corroding action of the elements, but by being subjected to heavier service than was anticipated in the original design. The engineer must therefore combine the functions of the prophet and the actuary and decide to what present expense it is worth while going in view of future contingencies.

There is more or less doubt in the minds of engineers as to the degree to which details of workmanship, manufacture, modes of construction, materials, etc., should be covered in their specifications. The only answer is "that depends." Where in these respects standardization has taken place and the engineer knows that the results are good, the task of specifying is comparatively simple. Much may be left to the contractor and manufacturer. Where, on the contrary, customary methods and materials are not appropriate to the work, the specifications of the engineer must be given in greater detail. Thus between the extremes of simply specifying the results desired, leaving methods and materials to those who do the work, and specifying how everything is to be done and the actual materials to be used there is wide latitude, and the medium to be adopted in every case depends largely on the general conditions of available manufacturing and contracting skill and capacity. Whatever may be the degree of detail to which he may carry his specifications the engineer cannot be relieved from the obligation of being well acquainted with the current practice of manufacturing and contracting firms, and with the materials with which he has to deal whether they be materials of construction or obstruction. The young graduate can have no better position in which to gain experience than that of contractor's engineer.

It would be well for specifications to cover not only the work to be performed by the contractor but also the data and assumptions underlying the engineer's project. While not absolutely necessary for the prosecution of the work, such information would be useful to the profession and for future reference, not to speak of its effect upon the engineer himself in increasing his sense of responsibility. The different classes of drawings referred to in the contract should be carefully defined in the specifications, otherwise ambiguities and uncertainties in interpretation will arise. Drawings may be looked upon as a species of shorthand invented to save words, time and expense, and the engineer should be an expert in reading drawings, and in writing them in such a way as to convey his exact meaning. Correct drawings and correct English both imply a competent knowledge of the subject of which they are the expression.

The engineer should know the cost of the work done under his supervision, not merely the cost to the proprietor, for that goes without saying, but also as far as possible the cost to the contractor. Not only should he keep in touch with the labor market, but he should take an interest in the physical and social welfare of the men under his charge. They should look upon

Convocation Hall, University of Toronto, where the joint meeting of the Canadian Society of Civil Engineers and Engineering Society was held him as a friend and not as an impersonal being concerned only in the results of their work. As between the contractor and the proprietor he must occupy the position of an impartial judge and not that of an advocate. The more thoroughly he knows his work the better able will he be to do his duty in this respect, and to retain the confidence of both parties. His knowledge of law and business should be sufficient to enable him to act harmoniously with those in charge of the legal and commercial interests connected with his work. In fine he must be a many-sided man, thoroughly acquainted with his own side of the work and able to cooperate with all sorts and conditions of men.

Engineers are naturally divided into classes according to the special nature of their work. For the purpose of mutual improvement in their specialties, these classes form societies, of which the main features are the reading of papers, the interchange of ideas and the extension of personal acquaintance. While these societies do a vast amount of good within their own spheres they are not capable of dealing with the question of the improvement of the engineering profession as a whole. The Canadian Society of Civil Engineers was formed in 1887 with this object. The charter reads: "The Canadian Society of Civil Engineers having for its objects and purposes to facilitate the acquirement and interchange of professional knowledge among its members and more particularly to promote the acquisition of that species of knowledge which has special reference to the profession of civil engineering, and further to encourage investigation in connection with all branches and departments of knowledge connected with the profession," etc.

The second by-law reads: "The term Civil Engineer as used in this Society shall mean all who are or have been, engaged in the designing or constructing of railways, canals, harbors, lighthouses, bridges, roads, river improvements or other hydraulic works, sanitary, electrical, mining, mechanical or military works or in the study and practice of navigation by water or air, or in the directing of the great sources of power in nature for the use and convenience of man."

It must be confessed after an existence of twenty-one years that the Canadian Society has not succeeded in gaining recognition by the various classes of engineers in the country as the representative and authoritative engineering society. Even in England the term "civil engineering" has not gained full recognition as embracing all branches of the profession.

The "New English Dictionary" edited by Sir James Murray and recognized as one of the greatest authorities on the language, gives among others the following definitions of the word engineer:

"2b. One who designs and constructs military works for attack or defence.

"3. One whose profession is the designing and constructing of works of public utility such as bridges, roads, canals, railways, harbors, drainage works, gas and waterworks, etc. From 18th century also civil engineer, not in Johnson 1775 or Todd 1818. The former has only the military sense to which the latter adds 'a maker of engines,' citing Bullokar.

"In the early quotations the persons referred to were probably by profession military engineers though the works mentioned were of a 'civil' character. Since 2b. has ceased to be a prominent sense of engineer the term 'civil engineer' has lost its original antithetic force but it continues to be the ordinary designation of the profession to which it was first applied, distinguishing it from that of mechanical engineer. Other phraseological combinations, as electric, gas, mining, railway, telegraph engineers are used to designate those who devote themselves to special departments of engineering.

"1792 Smeaton, Reports (1797) I Pref. 7. The first meeting of this new institution, the Society of Civil Engineers, was held on the 15th of April, 1793.

"1793 Edystone L. Introd. 8 'my profession of a civil engineer.' "

As Smeaton died in 1792, the dates 1797 and 1793 are probably the dates of publication of the reports. According to Sir Alexander Binnie, the first society of civil engineers in England was formed in London about the year 1760 by engineers who were in attendance at the Session of Parliament.

It seems, therefore, that the term "civil engineer" in England dates from about 1760 and that in the opinion of the editor of the New English Dictionary, who may be assumed to represent the public, it applies at present to engineers having to do with works of public utility such as those mentioned, but it is to be distinguished from the term mechanical engineer.

The same tendency to restriction of the term "civil engineer" exists in Canada and the United States not only among the public but in the profession as well. In all the great engineering schools this tendency is reflected.

The question now arises, is it worth while to expend further energy in resisting what appears to be a natural tendency? The only reason for the introduction of the term "civil" was that the word "engineer" had previously been monopolized by those engaged in military works; now that this distinction has lost its importance, would it not be better to drop the term "civil" as applied to the whole profession and confine it to the special applications justified by modern custom?

The profession as a whole should be represented in Canada by a single authoritative body somewhat after the pattern of the Medical Council or the Benchers of the Law Society in Ontario, to which should be entrusted the subjects of engineering education, qualifications for professional standing, professional ethics, etc., in short all questions of general professional interest. It is only by the hearty co-operation of the various classes of engineers that such a movement could succeed. The Canadian Society of Engineers with its Council would thus exercise functions which are necessary for the strengthening of the profession in its relations with the public, and which lie outside the province of the special engineering societies.

As a rule the engineer does not come immediately into contact with the public. At the same time there are questions of public interest in which he, in common with the chemist, the metallurgist, the biologist, the medical practitioner, the forester and others, is regarded as an authority. The public expects the engineer to aid by his advice in the improvement of transportation, the prevention of railway accidents, the abatement of smoke, the preservation and improvement of public health, transmission of power, the irrigation of arid lands, the economical management and conservation of forests and mines, the improvement of agricultural soils, the conservation of river flow, etc., etc. Such questions are matters of municipal and governmental policy and cannot be properly controlled by money-making corporations or individuals. Before a move can be made in these matters a strong body of enlightened public opinion must be formed, and who should be better qualified for the task of stimulating and guiding this public opinion than the engineer? If he is too busy or too backward to undertake this duty of his own accord, what about the editor of the engineering newspaper? The latter is never hampered by modesty and should write not only for his subscribers but for the public as well. He need not fear that his work will be lost; the lay press will print his good articles and give him due credit for them.

Mr. Carnegie is reported to have made the statement that at the present rate of consumption, the supply of iron ore (presumably the more important and richer ores) of the United States would be exhausted in forty years and the supply in England within seven years. He based this opinion on the best expert evidence he could obtain. If this statement be correct, what a prospect does it not open for the vast iron resources of Canada, and yet at the same time what a warning does it not convey to the government which controls these resources! In the United States the total production of pig iron up to the present is 350,000,000 tons of which over one-half has been made within the last ten years. The production of the world in 1907 was 61,000,000 tons, of which the United States are to be credited with 26,000,000, Germany with 13,000,000, Great Britain with 10,000,000 and other countries with 11,000,000. Canada produced 600,000 tons less than one per cent. of the total. In the United States the acid Bessemer process seems to have reached its maximum output and in the future will rapidly diminish in importance owing to the increasing scarcity of the requisite ores and its inability to use scrap. It is being rapidly superseded by the basic open hearth process, which can utilize ores containing a larger percentage of phosphorus and also all kinds of scrap.

The future of electric processes in iron and steel production in Canada will depend more upon the cost of hydro-electric power than on any other factor. Closely connected with the conservation of the iron and timber resources of America is the great Portland cement industry, which has sprung into importance within the last twenty years. The Canadian production in 1907 amounted to 2,400,000 barrels, the United States production to 49,000,000 barrels. Concrete and ferro concrete will replace steel and wood in construction in ever increasing quantities. As in the case of the electrometallurgy of iron, the cost of hydro-electric power is a large item in the manufacture of cement.

The conservation and regulation of river-flow for water power alone, to say nothing of transportation and irrigation, is a necessity for the future industries of the country. The regularity and volume of river-flow in its turn is dependent upon the preservation of forest growth, especially in the mountainous and upland regions. Forest conservation in fact is one of the fundamental conditions of future prosperity. And so one might go on, and enumerate one after the other, various sources of wealth and well-being now extravagantly exploited which demand for their wise development the knowledge and skill of the engineer. It is to be hoped that the conferences initiated by President Roosevelt to consider the conservation of natural resources will bear fruit in pointing the way to practical solutions of these national problems. Canada has already made a good beginning both in collecting information regarding our resources and in passing legislation.

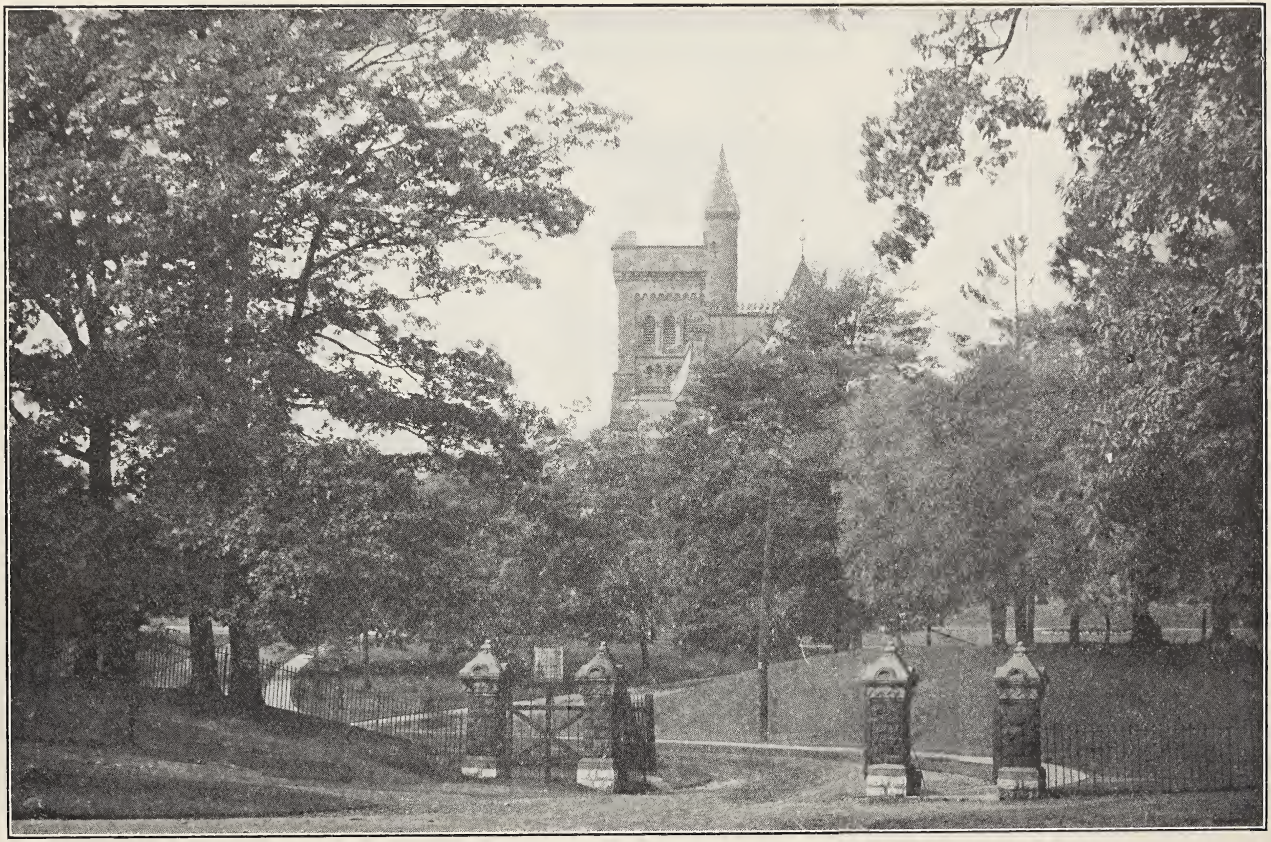
One of the most striking illustrations of modern economic tendencies is the increase which has taken place in the voltage of power transmission lines. Within the last twenty-five years the practicable voltage has been increased from 1,000 to 110,000 volts, thus immensely extending the possible area of distribution from the hydro-electric power plant.

In the machine shop, complex machine tools, largely the inventions of the mechanic, high speed tool steels, electric motor drives and high class organization have immensely increased the output and decreased unit costs. The steam turbine, the improved hydraulic turbine, electric lighting, electric traction, the gas engine, the great ocean and lake freighters, the monster liners and that concentrated essence of power, the modern battleship, have all come within the present generation and we cannot predict what changes in the application of power and machinery will take place before it passes away. It would not be surprising if the automobile were to displace electric transportation in cities and be replaced for purposes of pleasure by the aeroplane and the dirigible balloon. In the future, electric transportation may be confined to underground tunnels in the cities and largely replace steam power on railway lines through the country. Evidently the end of the work of the engineer is not yet at hand. The inventions of the present day, under the stimulus of science and the ever-increasing complexity of life, crowd so closely upon us that it is impossible to form a just estimate of their relative values. That must be left to the judgment of posterity looking backward through the long perspective of the years.

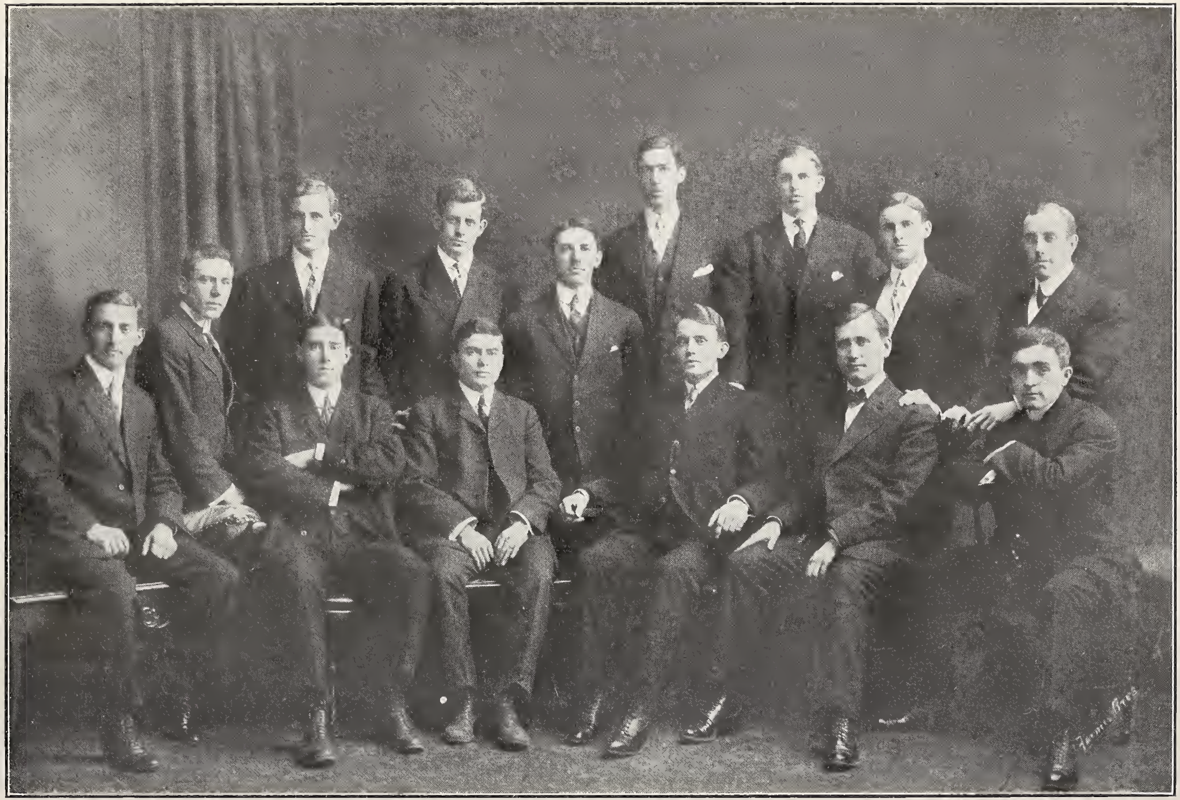
One of the first duties of a country is to work up within its own limits its raw materials into the forms in which they are to be finally used by individual consumers. Only in so far as this end is successfully accomplished will the manufacturing population of a country be increased and the cost of transportation of its products to a foreign country, in comparison with their value, be diminished. One effect of over-production or decreased profits is to stimulate invention for the purpose of reducing the cost of production and transportation. As a rule the first effect is to throw labor out of employment, but this is no argument against invention. Wages will fall in any case owing to the failing market for the product, and can be maintained only by the discovery of new markets. The decrease of cost due to labor-saving inventions leads to the extension of the markets without which production must be checked and labor seek new fields, or be reduced to a lower standard of living. Thus a country depends for material prosperity as much upon the brains of its scientific men, inventors and engineers as upon its natural resources. Money spent upon unproductive enterprises means waste of labor and the stoppage before long of the wheels of industry. Capital knows no country; it ever flows to the land of promise; let it be our endeavor to make Canada no mere land of promise but a land of fulfilment as well. Fortunate in possessing vast agricultural resources without which no nation can be self-sustaining, Canada can afford to take time in developing its mines. The mines are our treasure houses, which once emptied, can never again be filled—while the scattered gold, silver, copper and iron that remain in the country may to some extent be recovered after having fulfilled their first uses, the coal, oil, and gas once used are gone forever.

The preservation of our fisheries and forests demands our first attention. Their cultivation must begin and their mining must cease, if we are not to lose them altogether. Nor need the engineer fear that under such a policy his opportunities would be deferred or his field narrowed. The conservation of our resources will introduce many new problems, will stimulate research and invention, cheapen production, open up new markets and enable the country to sustain a much larger and more permanent population than we have any right to expect from a continuance of our present ill regulated and short-sighted practice of extravagant consumption and waste.

In conclusion I have to thank the members of the Society for the honor they conferred upon me a year ago in electing me to the highest office within their gift, an honor altogether undeserved on the score of previous service. I have also to thank my colleagues of the outgoing council for the kindly assistance which I have in many ways received from them in the performance of my special duties. I am sure that they join me in wishing the new council an increased measure of success in promoting the interests of the Society.



Eastern Entrance University of Toronto
University College in Background



EXECUTIVE COMMITTEE ENGINEERING SOCIETY 1908-9

UNIVERSITY OF TORONTO

F. D. Clark, Rec. Sec. W. J. Amsden, Librarian. F. H. Crosby, 3rd Year Rep. L. E. Jones, B.A., 1st Year Rep. F. H. Chestnut, Treas. R. H. New, 2nd Year Rep. G. H. Moody Cor. Sec. S. S. Gear 4th Year Rep.

A. R. Duff, Vice-Pres. Chem. and Min. L. R. Wilson, Vice-Pres. Mech. and Elec. T. H. Hogg, B.A.Sc., Grads. Rep. R. J. Marshall, President. K. A. MacKenzie, B.A.Sc., Editor. W. J. Boulton, Vice-Pres. Civil and Arch.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 MARCH, 1909 New Series Vol. 2, No. 5

TRANSMISSION LINE FORMULAE

T. R. ROSEBRUGH, M.A.

In making any calculation one may hesitate between a method which neglects quantities that may possibly need to be taken into account, and one which while dealing completely with the problem, is more laborious or intricate, and thus increases the chances of error. The advantage of the method to be described is that it permits a middle course, yielding first a rough result coinciding with that of simpler expressions, to be followed subsequently as far as may be desired, by rough approximations rapidly converging to the true result as term after term is estimated.

The result may be obtained graphically or analytically as may be preferred by the following method.

First reduce the problem, if it relates to three-phase transmission, to one of single phase.

If the connection be star, then in so far as the fundamental is concerned, the neutral points (one at each end) will be at the same potential, and may be treated as if in immediate contact. One-third of the power may then be taken as transmitted by each conductor at the voltage which exists between it and the neutral point, that is line voltage divided by $\sqrt{3}$.

The resistance and reactance are seen to be those of one conductor only, while the capacity and leakage conductance with which we have to do are estimated as the individual branches of a star connection having their common terminals on an imaginary neutral carrying no current.

In the calculation it is indifferent whether the actual arrangement be delta or star.

It is not the purpose of this paper to deal with these line constants, but a few words of caution may not be out of place. In using tables individual numbers may be in error, or a mistake may be made by using a table calculated on a different basis, perhaps with some coefficient not properly belonging, incorporated with it, and the special method of using such table not quoted from the original source.

Let $r =$ resistance of one conductor.
$x =$ reactance of one conductor.
$g =$ leakage conductance.
$b =$ susceptance.

If x be taken from a table, it should be, for the present purpose, one giving the reactance of one conductor at the given frequency, in accordance with

$$x = L\omega = \frac{160930}{109}\left(2 \log_e \frac{2D}{d} + \frac{1}{2}\right) m\, \omega \text{ henries,}$$

where m is the distance of transmission in miles, by stating its value for one mile, or otherwise.

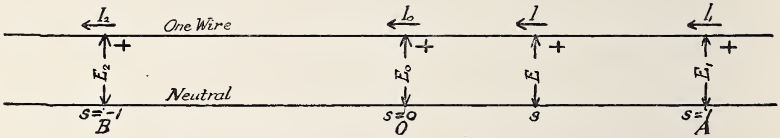
Also $b = C\omega$ should, if obtained from a table, be from one giving values agreeing with

$$C \times 10^6 = \frac{160930}{900000} m \div 2 \log_e \frac{2D}{d} \text{ microfarads.}$$

These preliminaries being arranged, and

$$z = r + x\,j$$
$$y = g + b\,j$$

adopted for abbreviation, take E_0 and I_0 to denote the vectors describing voltage and current respectively at one end of the line, which for definiteness may be thought of for the present as the receiving end at O in the figure, and taken as the origin.



Take E_1 and I_1 of corresponding meaning for the other end A at $s = 1$. E and I similarly may be taken as vectors for the arbitrary point on the line whose distance from O is s.

The diagram shows the convention adopted for the signs: that is, positive instantaneous values of voltage and current are taken to be of the polarity and sense respectively indicated by the + and the arrow, and relative vector senses chosen accordingly.

Here E and I being functions of s they are given thus by Taylor's theorem:

$$E = E_0 + s\left(\frac{dE}{ds}\right)_0 + \frac{s^2}{2}\left(\frac{d^2E}{ds^2}\right)_0 + \frac{s^3}{6}\left(\frac{d^3E}{ds^3}\right)_0 +$$

or for short, D denoting differentiation once with regard to s, D^2 twice, etc.

$$E = E_0 + s(DE)_0 + \frac{s^2}{2}(D^2E)_0 + \frac{s^3}{6}(D^3E)_0 +$$

$$I = I_0 + s(DI)_0 + \frac{s^2}{2}(D^2I)_0 + \frac{s^3}{6}(D^3I)_0$$

These values may be readily determined thus: With the current as at s remaining constant at the value I the vector voltage difference for the conductor would be zI for the whole length of the line, that is for unit length as we have chosen to call it so, and consequently $\frac{dE}{ds} = zI$, or for short $DE = zI$. Similarly $DI = yE$.

$$\begin{aligned}
\text{Hence } D^2E &= D.DE = DzI = zyE \\
D^3E &= D.D^2E = DzyE = z^2yI \\
D^4E &= D.D^3E = Dz^2yI = z^2y^2E \\
D^2I &= D.DI = DyE = yzI \\
D^3I &= D.D^2I = DyzI = y^2zE \\
D^4I &= D.D^3I = Dy^2zE = y^2z^2I
\end{aligned}$$

$$\text{Therefore } E = E_0 + szI_0 + \frac{s^2}{2}\,zyE_0 + \frac{s^3}{6}\,z^2yI_0 +$$

$$\text{and } I = I_0 + syE_0 + \frac{s^2}{2}\,yzI_0 + \frac{s^3}{6}\,y^2zE_0 +$$

In particular at A the end of the line ($s = 1$)

$$E_1 = E_0 + zI_0 + \frac{1}{2}\,zyE_0 + \frac{1}{6}\,z^2yI_0 +$$

$$I_1 = I_0 + yE_0 + \frac{1}{2}\,yzI_0 + \frac{1}{6}\,y^2zE_0 +$$

By means of these two expressions the problem (so far as fundamental frequency is concerned) may be solved as accurately as the data permit, for any length of line.

As the length and voltage increase it may be necessary to take in successively additional terms; this may be carried to any extent desired.

The first term for I_1 and the first two for E_1 give the ordinary solution for short lines at low voltage. The second term for I_1 namely $yE_0 = (g + bj)\,E_0$ corrects the current for leakage and effect of capacity. The third term for E_1 corrects the drop already calculated for constant current by taking account of its variation along the line due to leakage and capacity. The third term for I_1 corrects the error made in calculating leakage and capacity effect on the basis of constant potential throughout.

At or before this point, the requirements of calculations of power transmission are likely to be satisfied, but telephonic transmission with the high frequency of some of the components of sound necessary for clear enunciation, and the long distances which are common may demand several terms more.

It is unnecessary to discuss at length the method of using this formula, as the use of complex quantities is explained in many text books.

Briefly, however, it may be stated as a caution that while the laws of algebra may be applied to the expressions given, yet if E_0 is to be taken directly as a number, I_0 (not usually being a vector in the same direction) may not be. For example, if the current be 100 amperes at O, and be lagging so as to have a power factor of 90%, then if E_0 be represented by its value in volts as a pure number, $I_0 = 100\,p - 100\,qj$ where $p = .90$ and $p^2 + q^2 = 1$.

Thus the data may for symmetry be supposed stated in the form

$$E_0 = A_0 + B_0\,j$$
$$I_0 = M_0 + N_0\,j$$

There finally result from the above described calculation

$$E_1 = A_1 + B_1\,j$$
$$I_1 = M_1 + N_1\,j$$

As line drop is stated as the arithmetical difference in value of the line voltages it will be (when only the fundamental is considered)

$$\sqrt{3}\,\sqrt{A_1^2 + B_1^2} - \sqrt{3}\,\sqrt{A_0^2 + B_0^2}$$

The power transmitted will be $3(A_1M_1 + B_1N_1)$ watts, and that received $3(A_0M_0 + B_0N_0)$ from which the efficiency is at once found in per cent. $100\,\dfrac{A_0M_0 + B_0N_0}{A_1M_1 + B_1N_1}$

The power factor at A will be

$$(A_1M_1 + B_1N_1) \div \sqrt{A_1^2 + B_1^2}\,\sqrt{M_1^2 + N_1^2}$$

Again suppose the data given relate to the point O supplying power to the other end B of the line under given conditions represented by the same diagram as before. Then as every point on a continuous line may be considered as receiving power on one side and giving it out on the other, the point O may be so considered and the conditions at B found by inserting $s = -1$ in the formula. This will have the effect of changing from + to — the sign of each even numbered (odd powered) term in both the series given.

Therefore when the vectors E_0 and I_0 are given for the point O, E_2 and I_2 for the other end B of the line of the same length as before will be given by

$$E_2 = E_0 - zI_0 + \frac{1}{2}\,zyE_0 - \frac{1}{6}\,z^2yI_0 +$$

$$I_2 = I_0 - yE_0 + \frac{1}{2}\,yzI_0 - \frac{1}{6}\,y^2zE_0 +$$

These may be dealt with similarly.

THE DETERMINATION OF LATITUDE.

L. B. STEWART, O.L.S., D.T.S.
Professor of Surveying

In this article it is proposed to give a brief account of the principal methods of determining latitude which are adapted to the use of the surveyor's transit or the sextant, with a brief reference to the precise methods used in connection with a geodetic survey, or in the astronomical observatory.

The term *latitude* used in this connection applies to the astronomical latitude, which may be defined as the angle which the direction of the plumb line, or normal to the earth's surface, at the point of observation, makes with the plane of the equator. This line in general does not pass through the centre of the earth, the form of the earth being approximately spheroidal; and the angle which the line joining the point of observation to the earth's centre makes with the plane of the equator is termed the geocentric latitude. The latter cannot be found by observation, but its value can be computed in terms of the astronomical latitude, for a spheroid of given dimensions.

In Figure 1 PEP^1Q is a meridian section of the earth; P and P^1 the north and south poles, respectively; EQ the intersection of the planes of the meridian and the equator; A any point; AT the tangent, AN the normal, and AO the radius at A. AZ is the production of AN upwards, determining the point Z the observer's zenith. AN^1E is then the astronomical latitude, and AOE the geocentric.

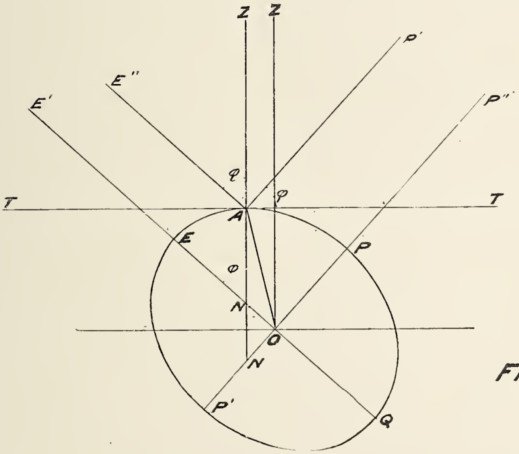


Fig 1

The maximum value of the angle OAN (the reduction of the latitude) is about 11′ 40″, occurring in latitude 45° 06′ 08″, about; and in latitude 45° the length ON or ON^1 is about nineteen miles.

If now AP'' be drawn parallel to OP'' and AE^1 to OE, then the angle ZAE^1 is equal to the observer's latitude (astronomical), and it is evident also that this angle is equal to $P''AT^1$.

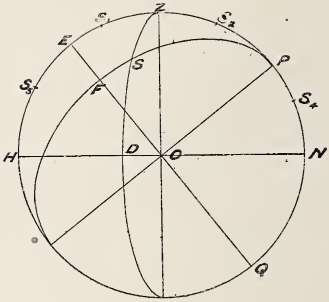


Fig. 2

Fig. 2 is a projection of the celestial sphere on the plane of the meridian. It appears to the writer to be more convenient to consider this sphere as infinite, than as finite in extent; we may then assume the parallel lines AP'' and OP'' to intersect its surface in coincident points at P; AZ and OZ in the point Z; and AE^1 and OE^1 in E. The latitude of A, from what has been shown above, is then equal to the declination of the zenith EZ, or altitude of the elevated pole PN; so that the determination of latitude is reduced to the determination of one or the other of these arcs.

Proceeding now to a discussion of the more usual methods of finding the latitude by observation we shall first describe the various methods depending upon observed altitudes or zenith distances of stars (using the term star to mean any heavenly body), taking first the method.

(1) By meridian altitudes or zenith distances.

It is assumed that the observer is provided with either a transit or a sextant, and knows how to use his instrument, so that we shall confine ourselves to a description of the mode of reduction of the observations only in each case.

If now the star be observed in either of the positions S_1, S_2, S_3 or S_4, and we denote by

δ the star's declination,
ζ its zenith distance, and
ϕ the latitude of the place

then evidently we have for the four positions, respectively

$$\phi = \delta + \zeta \tag{1}$$
$$\phi = \delta - \zeta \tag{2}$$
$$\phi = \zeta - \delta \tag{3}$$
$$\phi = 180^\circ - \delta - \zeta \tag{4}$$

If a south declination be regarded as negative, then equation (3) is included in (1).

Again, if we denote by

p the star's polar distances, and
h its altitude

then for the positions S_2 and S_4 we may write, respectively

$$\phi = h - p \tag{5}$$
$$\phi = h + p \tag{6}$$

The star's declination is interpolated from the Nautical Almanac for the instant of observation.

Again, for two stars in the positions S_1 and S_2 we may write

$$\phi = \delta + \zeta$$

$$\phi = \delta^1 - \zeta^1$$

when by taking the mean we have

$$\phi = \frac{\delta + \delta^1}{2} + \frac{\zeta - \zeta^1}{2} \qquad (7)$$

so that it is only necessary to know the difference of the zenith distances of the two stars, not their absolute values. This quantity may be observed as follows with a surveyor's transit: The vertical axis of the instrument having been carefully plumbed, point to one of the stars S_1 or S_2 when on the meridian and read the vertical circle; then turn in azimuth through 180° and point to the other star when at the instant of transit and read again. The difference of the two vertical circle readings is the required difference of zenith distance.

For this observation the alidade of the vertical circle should be provided with an accurate level to indicate any change of inclination of that part of the instrument.

The method just described is the same in principle as Talcott's method of finding the latitude, the instrument specially designed for the purpose being the zenith telescope. This instrument is essentially an alt-azimuth in which the circles play a subordinate part, being used only for finding; while the important parts of the instrument are the filar micrometer placed in the focus of the telescope, and the sensitive latitude level attached to the alidade. In order that the micrometer may be used to measure the difference of zenith distance of the stars of a pair, they must be so selected that their zenith distances differ by less than the angular field of view of the telescope. In observing, the telescope is set at the mean zenith distance of the two stars, which are then bisected in turn by the micrometer thread of the telescope as they cross the meridian, the instrument being turned through 180° in azimuth between the observations. The difference of the micrometer readings, multiplied by the angular value of a turn of the screw, and corrected for change of inclination as indicated by the level, and for differential refraction, gives the required difference of zenith distance of the two stars. This quantity added to the mean of the declinations gives the latitude, as shown by equation (7).

The advantages of the zenith telescope as compared with the alt-azimuth in taking the above observation are apparent after a moment's consideration. In the first place, other things being equal, the precision of the former instrument should exceed that of the latter in the ratio of the focal length of the telescope of the former to the radius of the vertical circle of the latter instrument. In addition to this, however, there are the errors of a graduated circle, when its diameter exceeds twelve or fifteen inches, due to flexure, varying temperature, etc., as well as those of the graduations themselves, which completely nullify the advantage that would otherwise be gained by increasing its diameter, and thus place still more to the credit of the zenith telescope. The errors and irregularities of a micrometer screw, on the other hand, can be readily investigated.

These advantages, together with the extreme portability of the zenith telescope, render Talcott's method the most useful one known for determining latitude in the field in connection with a geodetic survey.

(2) By an altitude out of the meridian, the time of observation being known.

This method involves a solution of the astronomical triangle ZPS (Fig. 2), the data being:

$$ZS = 90^\circ - h$$
$$PS = 90^\circ - \delta$$
$$ZPS = t \text{ (the hour angle of the star)}$$

and the required part is

$$ZP = 90^\circ - \phi$$

If the body observed is the sun, then t is the apparent time; if a star, then

$$t = \alpha - \Theta \text{ (if east of the meridian)}$$

or

$$t = \Theta - \alpha \text{ (if west of the meridian)}$$

In these equations Θ is the sidereal time of observation, and α the star's right ascension.

The fundamental relation connecting the given and the required quantities is

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t \qquad (8)$$

which is adapted for use by the introduction of the auxiliary θ as follows: Writing the equation

$$\sin h = \sin \delta\ (\sin \phi + \cos \phi \cot \delta \cos t)$$

then assuming

$$\cot \theta = \cot \delta \cos t$$

and substituting, we have

$$\sin h = \sin \delta\ (\sin \phi + \cos \phi \cot \theta)$$
$$= \frac{\sin \delta \cos (\phi - \theta)}{\sin \theta}$$

whence

$$\cos (\phi - \theta) = \frac{\sin h \sin \theta}{\sin \delta} \qquad (9)$$

θ being given by the relation

$$\tan \theta = \frac{\tan \delta}{\cos t} \qquad (10)$$

Equations (9) and (10) determine ϕ.

It is important in using any method to determine under what conditions errors in the data have the least effect upon the quantity computed from them. To investigate this we differentiate (8) and by obvious substitutions obtain

$$d\,\phi = -\cos C \sec A.\,d\,\delta + \sec A.\,d\,h + \cos \phi \tan A.\,d\,t \qquad (11)$$

in which C is the parallactic angle ZSP, and A the azimuth PZS. Regarding the errors as differentials this gives the effect of errors in the data upon the resulting latitude. It also shows that in order that the effects of these errors should be as small as possible A must be small and C large; though with small instruments this last condition is not important, as the error in δ will then be extremely small compared with the errors of the observed quantities. All these conditions are fulfilled, however, in the case of a close circumpolar star observed at or near elongation. This suggests:

(3) The method by an altitude of the pole star.

This method only differs from that last described in the mode of reduction. On account of its small polar distance, the altitude of the star can never differ much from the latitude of the place; the method therefore consists in computing a correction to apply to the former quantity to give the latter. An expression for this correction is derived as follows:

In eq. (8), writing

$$\phi = h + x$$
$$\delta = 90^\circ - p$$

it becomes

$$\sin h = \sin (h + x) \cos p + \cos (h + x) \sin p \cos t$$

Then expanding the sine and cosine of $h + x$, and then the sines and cosines of x and p and retaining only the first and second powers of these quantities, we have

$$\sin h = (\sin h - \frac{x^2}{2} \sin h + x \cos \mathrm{h}) \ (1 - \frac{p^2}{2})$$
$$+ (\cos h - \frac{x^2}{2} \cos h - x \sin h) \ p \cos t.$$

Then multiplying out and re-arranging, we have

$$x = - p \cos t + \tfrac{1}{2} \ (p^2 + x^2 + 2\, p\, x \cos t) \tan h$$

Then assuming as a first approximation

$$x = - p \cos t$$

and substituting in the second term, we get

$$x = - p \cos t + \tfrac{1}{2}\, p^2 \sin {}^2 t \tan h$$

Therefore we have finally, p being in seconds of arc

$$\phi = h - p \cos t + \tfrac{1}{2}\, p^2 \sin 1'' \sin {}^2 t \tan h \qquad (12)$$

The omitted terms in this expression will never exceed 0.″5.

An example is here given to illustrate the use of this expression.

The following observations were taken by the writer on June 14th, 1904, with a 3-in. transit reading to 1′:

Circle.	V. C. R.	Watch.
R.	45° 44′	14 h. 50 m. 04 s.
L.	45 43	53 46
R.	45 45	57 10
L.	45 44	59 44

The watch was regulated to sidereal time and its correction was — 20ˢ.

Taking the mean of the first two observations the reduction is as follows:

Mean of altitudes = $45° 43' 30''$
Refraction = 57

$h = 45\ 42\ 33$

Mean of observed times = $14^h\ 51^m\ 55^s$
Correction = -20

Sid. time = $14\ 51\ 35$
Star's r. a. = $1\ 24\ 26$

$t = 13\ 27\ 09$
$= 201° 47' 15''$

$\delta = 88° 47' 27''$
$\therefore\ p = 4353''$

log p = 3.638789
" cos t = 9.967813 n

" -4042 = 3.606602 n

" 0.5 = 1.698970
" p^2 = 7.277578
" sin $1''$ = $\bar{6}.685575$
" sin ^2t = 9.139134
" tan h = 10.010752

" 6.49 = 0.812009

$h = 45° 42' 33''$
1st correction = $1\ 07\ 22$
2nd correction = 6

$\phi = 46\ 50\ 01$

The mean of the last two observations having been reduced in the same manner, the result is

$$46° 50' 14''$$

and the mean of these two results:

$$\phi = 46° 50' 08''$$

The seconds are of course uncertain.

We shall proceed next to a description of one of the most useful methods, when small instruments are used, viz:

(4) By circum-meridian altitudes.

This term is applied to altitudes of a star when near the meridian. If a number of altitudes are observed, beginning when the star is east of the meridian and continuing until it has reached about the same hour angle west of the meridian, the method of reduction is to compute a correction to apply to each altitude to give a value of the meridian altitude. The mean of all the values so found is then taken and the latitude deduced therefrom by one of the equations (1), (2) or (3).

To derive an expression for this reduction we again return to equation (8), writing it in the form

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \,(1 - 2 \sin^2 \tfrac{1}{2} t)$$

which becomes

$$\sin h = \cos (\phi - \delta) - \cos \phi \cos \delta .\ 2 \sin^2 \tfrac{1}{2} t$$

Then denoting by ζ_0 the meridian zenith distance we have by (1)

$$\phi - \delta = \zeta_0 = 90^\circ - h_0$$

$$\therefore\ \sin h_0 - \sin h = \cos \phi \cos \delta .\ 2 \sin^2 \tfrac{1}{2} t$$

Then substituting

$$h = h_0 - x$$

in which x is the required correction to h, we have

$$\begin{aligned} \sin h &= \sin (h_0 - x) \\ &= \sin h_0 \left(1 - \frac{x^2}{2}\right) - x \cos h_0 \\ &= \sin h_0 - x \cos h_0 - \frac{x^2}{2} \sin h_0 \end{aligned}$$

$$\therefore\ \sin h_0 - \sin h = x \cos h_0 + \frac{x^2}{2} \sin h_0$$

and $\therefore$

$$x + \frac{x^2}{2} \tan h_0 = \frac{\cos \phi \cos \delta}{\cos h_0}\, 2 \sin^2 \tfrac{1}{2} t$$

Then omitting the term containing x^2 for a first approximation and substituting the value of x thus obtained in the omitted term, we obtain

$$\begin{aligned} x = {} & \frac{\cos \phi \cos \delta}{\cos h_0}\, 2 \sin^2 \tfrac{1}{2} t \\ & - \left(\frac{\cos \phi \cos \delta}{\cos h_0}\right)^2 \tan h_0\, 2 \sin^4 \tfrac{1}{2} t \end{aligned}$$

$\therefore$ in seconds of arc

$$\begin{aligned} h_0 - h = {} & \frac{\cos \phi \cos \delta}{\cos h_0} \cdot \frac{2 \sin^2 \tfrac{1}{2} t}{\sin 1''} \\ & - \left(\frac{\cos \phi \cos \delta}{\cos h_0}\right)^2 \tan h_0 \frac{2 \sin^4 \tfrac{1}{2} t}{\sin 1''} \quad (13) \end{aligned}$$

A sufficiently close value of ϕ for use in the right-hand member may be found by taking the greatest observed altitude and treating it as the meridian altitude, thus finding h_0 and therefrom an approximate value of ϕ. Tables may be found in most works on practical astronomy that give the values of the terms

$$\frac{2 \sin^2 \tfrac{1}{2} t}{\sin 1''} \ \& \ \frac{2 \sin^4 \tfrac{1}{2} t}{\sin 1''}$$

for argument t. The second of these quantities amounts to 1″

for $t = 18^m$, and to $7.''5$ for $t = 30^m$, so that with small instruments this term is seldom required.

Example.—The following observations were taken by the writer with a sextant and artificial horizon on September 2nd, 1893, at a place in approximate longitude $7^h\ 50^m$ W.:

2^2 alt. $\underline{\odot}$	Watch.
89° 59′ 15″	$12^h\ 32^m\ 36^s$
90 00 15	35 37
90 00 45	38 28
89 59 15	42 57
89 58 30	44 46
89 57 30	46 11
89 55 15	48 13

Index error = 0″

Watch correction = — $39^m\ 08^s$

An approximate value of the latitude is found from the maximum observed altitude as follows:

Max. 2-alt. = 90° 00′ 45″
Eccentric error = + 2 00
2) 90 02 45
Observed altitude = 45 01 22
Refraction = 58
45 00 24
Semi-diam. = 15 54
45 16 18
Parallax = 06
h_0 = 45 16 24
ζ_0 = 44 43 36
δ =+ 7 37 54
ϕ (approx.) = 52 21 30

The computation then proceeds as follows:

App. time at noon = $12^h\ 00^m\ 00^s$
Eq. of time = —21
Mean time = 11 59 39
Watch correction = 39 08
Watch time of noon = 12 38 47

Subtracting this in turn from the observed watch times gives the corresponding hour angles.

$$\begin{array}{ll} \log\cos\phi & = 9.785843 \\ \log\cos\delta & = 9.996136 \\ \hline \log\cos h_0 & = 9.847403 \\ \hline & \ 19.781979 \\ & \ \ 9.934576 \\ \hline \end{array}$$

Adding to this logarithm in turn those of

$$\frac{2\sin^2 \frac{1}{2} t}{\sin 1''}$$

corresponding to the values of t found as explained above, the values of the above term being taken from a table, we obtain the logarithms of the numbers of seconds contained in the second column below. The first column contains the zenith distances of the sun found from the observed double-altitudes in the manner exemplified above.

ζ	Corr'n	ζ_0
44° 44′ 21″	1′ 05″	44° 43′ 16″
43 51	17	34
43 36	00	36
44 21	29	52
44 43	1 00	43
45 13	1 32	41
46 21	2 30	51

$$\begin{array}{rl} \text{Mean} = & 44 \quad 43 \quad 39 \\ \delta = + & \ \ 7 \quad 37 \quad 54 \\ \hline \phi = & 52 \quad 21 \quad 33 \\ \hline \end{array}$$

This differs by only 3″ from the approximate value above found.

To use either of the last three methods a knowledge of the correction of the watch on local time is necessary; if this be unknown, it may be determined, as well as the latitude, by the following method:

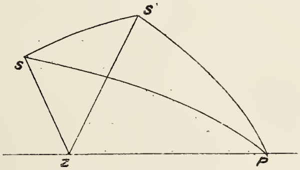


Fig 3

(5) By two altitudes of a star, or the altitudes of two stars, and the elapsed time between the observations.

S and S^1 (Fig. 3) are the two positions, either of the same star or of the two stars, at the instants when they are observed. It is necessary first to find the difference of their hour angles SPS^1. If the same star be observed at both observations, it is the elapsed sidereal interval between the observations; but if different stars be observed, and if

T and T^1 be the observed times, and

α and α^1 the stars' right ascensions,

then the difference of right ascension of the stars must receive a correction equal to the elapsed sidereal interval between the observations, or

$$SPS^1 = T^1 - T - (\alpha^1 - \alpha)$$

Then PS and PS^1 being known, the triangle SPS^1 may be solved, finding SS^1 and the angle PSS^1. The three sides of the triangle ZSS^1 are now known, so that it may be solved, finding the angle ZSS^1. Then $PSZ = ZSS^1 - PSS^1$. In the triangle PZS the two sides PS and ZS and their included angle are now known, so that it may be solved, finding PZ the required co-latitude. Completing the solution of the triangle ZPS we have in addition the hour angle ZPS and the azimuth PZS; so that this observation may be used to find the watch correction, and also to establish the direction of the meridian line if a transit be used.

This problem also admits of a graphical solution upon an artificial globe. Thus if the two arcs PS and PS^1 be drawn from any assumed point P on the globe, making the angle SPS^1 with one another, and if two small circles be described with S and S^1 as centres, and having angular radii equal to the zenith distances of those points found from the observations; the intersections of those circles is the position of the observer's zenith; whose angular distance from P is the co-latitude. As the circles must intersect in two points, the solution is ambiguous, but in practice an observer has always a knowledge of his latitude sufficiently close to enable him to determine which of the two values applies to his position.

There is another graphical solution of this problem which may be constructed upon a terrestrial globe, and which will serve to determine the longitude as well as the latitude, if a chronometer is used in the observations whose correction on Greenwich time, or on that of some known meridian, is given. This method is briefly as follows: If the zenith distance of a star be observed at any point on the earth's surface, the position of that point must lie on the circumference of a small circle, traced on the surface of the globe, whose angular radius is the zenith distance of the star, and whose centre is the point on the earth's surface over which the star is vertical at the instant of observation. This latter point is situated at the intersection of the meridian whose longitude is equal to the Greenwich hour angle of the star, with the parallel whose latitude is equal to the star's declination. The observations thus furnish data by which the radii and the positions of the centres of two such "circles of position" may be found; the declinations being of course taken from the Nautical Almanac. The place of observation is then situated at one of the points of intersection of the two circles thus found. That there are two points of intersection shows that there are always two points on the earth's surface at which the same observations may be taken at the same instant of time. As the position of a point is best determined by two circles which intersect at right angles, the observer using this method will consequently choose two stars whose azimuths differ by 90°, as nearly as possible.

All the methods above described depend upon altitudes of heavenly bodies, which are affected by refraction, and which must be corrected therefor; some methods will now be given in which the observed quantity is not affected by refraction. The first to be considered is

(6) By transits of stars across the prime vertical.

Any star whose declination lies between the limits 0° and ϕ will cross the prime vertical twice in its diurnal course. In Fig. 4, S and S^1 are the two positions of a star when on the

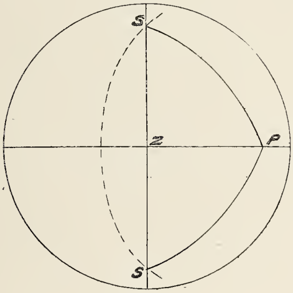


Fig. 4

prime vertical. If now the sidereal times of transit of a star be observed by means of a transit instrument adjusted in the prime vertical, the elapsed interval of time between the transits gives the angle SPS^1, and from the equality of the two triangles ZPS and ZPS^1 it follows that half the observed interval of time between the transits is equal to ZPS, the hour angle of the star when on the prime vertical. The azimuth of the star being 90° we have at once the relation

$$\tan \phi = \frac{\tan \delta}{\cos t} \tag{14}$$

which gives the latitude.

The altitude and hour angle of a star when on the prime vertical, the latitude being known approximately, are given by the equations

$$\sin h = \frac{\sin \delta}{\sin \phi} \qquad \cos t = \frac{\tan \delta}{\tan \phi} \tag{15}$$

and the sidereal time of transit then follows from the relation

$$\Theta = \alpha + t$$

These quantities are necessary in preparing for an observation.

This method is not much used with small instruments, but with the portable astronomical transit instrument it is one of the most accurate methods known for determining latitude. It was at one time much used for field observations, but has been superseded by Talcott's method. With the more precise instrument a considerable departure is made, in the reduction of the observations, from the simplicity of the method by equation (14), account being taken of the small deviation of the instrument in azimuth, the inclination of the rotation axis, and the collimation constant; and in some of the modifications of the method the azimuth and collimation constants are determined by the observations themselves, so that their effect upon the resulting latitude is entirely eliminated.

Another method which has recently been developed, and should prove a useful one, is

(7) By observations of stars at elongation.

When at elongation the parallactic angle of a star is a right angle, and the following relation exists between the azimuth and declination of the star and the latitude of the place.

$$\sin A = \frac{\cos \delta}{\cos \phi}$$

If now there are two stars that are at elongation within a few minutes of each other, one east and the other west of the meridian, then we have the two equations:

$$\sin A_1 = \frac{\cos \delta_1}{\cos \phi} \qquad \sin A_2 = \frac{\cos \delta_2}{\cos \phi} \qquad (16)$$

whence

$$\frac{\sin A_1}{\sin A_2} = \frac{\cos \delta_1}{\cos \delta_2}$$

from which by composition and division we have

$$\frac{\sin A_1 + \sin A_2}{\sin A_1 - \sin A_2} = \frac{\cos \delta_1 + \cos \delta_2}{\cos \delta_1 - \cos \delta_2}$$

From this we find

$$\tan \tfrac{1}{2} (A_1 + A_2) =$$
$$- \cot \tfrac{1}{2} (\delta_1 + \delta_2) \cot \tfrac{1}{2} (\delta_1 - \delta_2) \tan \tfrac{1}{2} (A_1 - A_2)$$

or $\tan \tfrac{1}{2} (A_1 - A_2) =$

$$- \tan \tfrac{1}{2} (A_1 + A_2) \tan \tfrac{1}{2} (\delta_1 + \delta_2) \tan \tfrac{1}{2} (\delta_1 - \delta_2) \qquad (17)$$

Now the sum of the azimuths of the two stars may be observed by pointing the telescope of a transit to the stars in turn, when at elongation, and reading the horizontal circle at each pointing; the difference of the readings is the sum of the azimuths. On finding the difference of the azimuths by equation (17), the sum and difference then give the separate azimuths. The latitude then follows from either of the equations:

$$\cos \phi = \frac{\cos \delta_1}{\sin A_1} = \frac{\cos \delta_2}{\sin A_2} \qquad (18)$$

It can be shown theoretically that the best stars for observation are those whose declinations exceed the latitude as little as possible, and therefore whose azimuths are large and zenith distances small when at elongation. There is a practical limit, however, beyond which this principle cannot be carried; as at small zenith distances the effect of inclination of axis or collimation error becomes very marked. The former varies as the cotang., and the latter as the cosec., of the zenith distance, and therefore the errors in these adjustments will be multiplied by those ratios, so that the total effect of instrumental errors may be very noticeable. This effect, however, may be largely eliminated by observing a second pair, or each alternate pair, of stars, with the instrument reversed.

The above method was due to Prof. J. S. Corti, of the National Engineering School, San Juan (Arg. Rep.)

A few years ago the writer adapted this method to the observation of any number of stars on a given night, observing east and west stars in any order, but preserving an approximate equality in their numbers. Each star observed furnishes an equation of the form

$$d\,\phi \tan \phi^1 \mp c \tan \delta \pm d\,R_0 \cot A^1 + \frac{1}{\sin 1''}\left(\frac{\cot \delta}{\sin A^1 \cos \phi^1} - 1\right) = O \qquad (19)$$

in which

ϕ^1 denotes an assumed approximate value of the latitude,
$d\phi$ a correction to this value, to be determined,
c the collimation constant of the instrument
$d\,R_0$ a correction to $R_0{}^1$, the assumed meridian horizontal circle reading
A^1 an approximate azimuth of the star, given by the equation

$$A^1 = (R^1 + b \tan h) - R_0{}^1$$

where

R^1 is the horizontal circle reading on pointing to the star, and
b the inclination of the horizontal axis.

Upper signs are to be used for an eastern elongation, and lower signs for a western.

The unknowns in the above equation are $d\phi$ c and $d\,R_0$. An equation is formed for each star observed—the number of stars being at least three—and the resulting equations are solved by least squares. As the collimation constant is determined by the reduction its effect is eliminated from the result.

An account of this method by the writer is given in No. 16 of the transactions of the Engineering Society.

The above methods for determining latitude are the best available when the most precise results are desired. There are, however, some approximate methods which are sometimes useful to the explorer; as, for instance, that by observing the azimuth of a heavenly body with a compass, when rising or setting; or by observing the rate of change of zenith distance of a heavenly body when near the prime vertical. This last method deserves perhaps more than a passing notice, on account of the ease with which it can be applied. By differentiating equation (8) we have

$$\cos h \frac{d\,h}{d\,t} = -\cos \phi \cos \delta \sin t$$

or

$$\frac{d\,\zeta}{d\,t} = \frac{\cos \phi \cos \delta \sin t}{\cos h}$$

But

$$\frac{\sin t}{\cos h} = \frac{\sin A}{\cos \delta}$$

$\therefore$

$$\frac{d\,\zeta}{d\,t} = \cos \phi \sin A$$

or

$$\cos \phi = \frac{d\,\zeta}{d\,t} \operatorname{cosec} A \qquad (20)$$

the required expression for the latitude.

This formula can best be applied by noting the interval of time that the sun requires to change its zenith distance by an amount equal to its angular diameter, by observing its transit across the horizontal thread of a transit, which is firmly clamped in altitude. The observation may also be taken with a sextant, by noting the times of contact of the two images of the sun, keeping the index firmly clamped during the observation. The sun's angular semi-diameter is given by the Nautical Almanac, which is half the change of zenith distance.

The advantage of the method lies in the fact that the declination of the sun does not enter into the problem; and this statement also applies to refraction, as the altitude is the same at both contacts. If the observation is made near the prime vertical the azimuth need only be known approximately.

To show, however, that caution must be observed in using these approximate methods, we shall determine the effect of a small error in the observed interval dt. Differentiating equation (20) we find

$$d\phi = \frac{d\,(dt)}{dt \tan \phi \sin 1''} \qquad (21)$$

which shows in the first place that the error diminishes as the latitude increases, assuming that large and small values of dt can be observed with equal precision. Then applying the expression to an example by taking

$$d\,(dt) = 1^s \qquad dt = 217.^s6 \qquad \phi = 43° \; 40'$$

we find

$$d\phi = 16' \; 33''$$

which is the error in the latitude resulting from an error of 1^s in the observed time interval. It is clear then that it is only by taking the mean of the results of a large number of observations that we can hope to obtain even an approximation to the truth.

DISCUSSION—THE YOUNG CIVIL ENGINEER

DISCUSSION BY HENRY W. HODGE

At Mr. Stern's request I join in the discussion of his article on "The Young Civil Engineer," though I do not think that I can add anything of value to his able advice to the technical graduate.

The technically educated engineer is rapidly advancing the profession of civil engineering, and we are no longer looked upon as high grade mechanics, as we were but a short time ago, but the public recognize the modern civil engineer not only as a man of high scientific training, but also as a public benefactor, as his achievements have made him a leader in advancing the development of the earth's natural resources and bringing the benefits of modern civilization within the reach of all. It should, therefore, be the aim of all young engineers to keep advancing this standing of the profession, and this can only be done by men of well rounded education and general knowledge; men who can favorably impress other men, and who can "shine" not only among their own professional associates who know their technical ability, but also among men of other walks of life who must be impressed with their ability before they will entrust great enterprises to their direction.

Therefore, I would advise every young engineer to try to add to his general knowledge, either by a classical course in college or by reading and travel, so that he will have a general knowledge of matters outside the world of science, in which we are apt to become uninteresting "experts."

While Mr. Stern's advice to change early positions occasionally so as to gather varied experience is good, I have found the young engineer rather inclined to change too often, as he finds the doing of the same thing for a length of time monotonous, and gets tired and desires a change, so that he is liable to lose that absolute confidence which comes only by doing a thing until it becomes second nature, so my advice is to learn to do at least one thing thoroughly, and if you can properly apply this special ability, you are bound to succeed. There are many brilliant engineers who are unknown because they have not the ability to impress their knowledge on men who require engineering services. You must not only be confident of your own ability to carry out great engineering undertakings, but you must be able to make the "captains of industry" and the "Napoleons of

---

Henry W. Hodge, Consulting Engineer, New York City. Mr. Hodge is a graduate of Rensaeller and a member of the firm of Boller & Hodge, who are the leading bridge engineers in professional practice in the United States. They have just been recently retained as engineers for the new bridge to built over the Mississippi River at St. Louis. They were also the engineers for the Singer Tower, New York City.

finance" share your confidence, and to do this you must make clear and concise statements of engineering matters, and yet free from details and technicalities which only confuse the man of affairs, you must be able to write a short letter that clearly defines the subject matter, and you must at all times be sure that your employer is confident that you know what you are about and can rid himself of all responsibility in the assurance that he has a fully competent engineer with good technical training. With a broad general knowledge of men of the world, and a personality which impresses men with your ability, you are bound to succeed, as never was the engineering field so large or the demand for engineers who have the knowledge and the daring to attempt large enterprises so great.

DISCUSSION BY ROBERT BREWSTER STANTON.

Mr. Eugene W. Stern has requested me to discuss his paper "The Young Civil Engineer," published in the January number of "Applied Science." Mr. Stern's paper covers the field so well as to character, duties and work of a young civil engineer which should tend to make him a success in his chosen profession, that I have but one remark to make upon the paper as it is.

The qualifications required to start with, given by Mr. Stern as "endurance of mind and body, adaptability, thoroughness, efficiency, intensity and imagination for possibilities," and all the other good qualities enumerated, are magnificent traits of character, but they are not necessarily peculiar to the make up of an engineer. They are all good and serviceable, but just as applicable to any other profession, trade or occupation. The real—and hence successful—engineering requires something else to start with.

One of my assistants in the building of the Cincinnati Southern Railway, after spending several years on that work in the Cumberland Mountains of East Tennessee, gave the qualifications of a young engineer thus:—"He must be composed of one-third mule, one-third dog and one-third angel; the mule to be able to stand the labor, the dog to stand the kicks, and the angel to enable him to carry through his work in a cheerful manner." These qualities were peculiarly requisite during the earlier railroad construction in the Rocky Mountain region and beyond, where he later went. But my friend left out the one pre-requisite—a quality which he himself did not possess. He had nearly all—if not every one—of the qualities enumerated by Mr. Stern, and a technical education far superior to most suc-

---

Robert B. Stanton, New York City. Mr. Stanton is a consulting and mining engineer with an international reputation. In 1889 he made a survey through the Grand Canyon of Colorado—a very daring undertaking. He has also explored in Sumatra and Java. He is a graduate of Miami University.

cessful engineers, and yet he soon quit engineering and went to farming.

This pre-requisite necessity of which I am speaking is very hard to define accurately. To begin with, the engineer—like the poet—is born, not made, and in that borning he is given a quality which I may call the engineering instinct, which can be acquired in no other way. We all recognize the fact that there is an indescribable quality, trait or something that goes to make the poet, the artist, which all the good qualities of body, mind or soul, and all the education in the world cannot produce, though they may train and improve it. Is it not so—and even to a greater degree—with the profession of engineering—whether civil, mining, mechanical, electrical or what not?

If this is so, then the first thing for a young engineer—or more properly speaking, a young man who hopes some day to become an engineer—is to find out whether he possess that inborn instinct. How, with his want of experience, is he to satisfy himself of this fact? That is not an easy question to answer, but the evidence of the fact begins with a love, a real all pervading love, of doing things for the very sake of the things accomplished; that is, a love of accomplishing such things as are included in the noted definition by Telford of the profession of civil engineering, found in the first charter of the Institution of Civil Engineers. The love will become stronger and stronger, and when it is founded on that true, inborn instinct, one can no more help being an engineer than he can help breathing and continue to exist. I spent many years with Mr. Jacob Blickensderfer, that famous railway engineer of the west, in locating and building some of the early Rocky Mountain and Pacific railways, and I said to him one day while he was Chief Engineer of the Union Pacific and nearly 70 years old, "Mr. Blickenderfer, why don't you quit such trying work and rest?" He replied, "I know it is a dog's life, but I can't quit. I love it."

This natural born love of an engineer's work should not be confused with ordinary "bent of mind;" I think it is something more. Robert Burns had a bent of mind for several things other than poetry, but it was his poet's nature and poet's love that compelled him to write those sweet songs that have touched the hearts of men and women all over the world.

The young man, then, the prospective engineer, having discovered that he posseses that inborn instinct, what is his next step? Educate it, cultivate it, in every way possible—in college, in the university, in the professional school. Is a thorough technical training in advance absolutely necessary for the success of every engineer? James B. Eads was a most noted and successful engineer—he was truly born one—yet he lacked in his preparation for his work that thorough technical training such as is now given in our great engineering schools, in fact, he never went to any school after he was thirteen. If any young man has the time and means at his disposal he should go to the very limit in his education—the technical education of an engineer—that is, acquire the most perfect tools with which to execute his future work. If, however, this cannot be done, there is still a place, and a successful career, for a young man with a good, ordinary high school or college education even in the profession of engineering. The necessary technical knowledge can be acquired as he goes on with his work—in his room at night, or around the camp fire in the wilderness. It has been done many, many times, and can be done again, that is, provided he has been educated and trained in his preparatory studies or around the fireside at home, to think clearly, reason correctly, and has the ability to put two and two together when he sees them separately in the many conditions of nature. This may seem a trite remark, but is not the fact that a large proportion of "young engineers" coming from the great technical engineering schools have their brains full of the details of technical knowledge, abstruse deductions and mathematical formulae—usually only committed to memory—and with only a minimum amount of ability to think clearly and reason logically; and the saddest absence of the power to put together the various "twos" found in nature which at first sight seem to be separate and distinct phenomena, and yet which are in truth intimately connected, and when in many cases their union, if recognized, would be found to be the direct cause of the effect so easily and clearly visible to anyone? And again, is not the lack of this ability, as above stated, the cause of the failure of so many young men who start into the profession, to become even "young engineers"? This has been my experience with the majority of young men who have been associated with me in engineering work.

A more extended discussion of this phase of the subject will be found in Vol. 53, page 307, Trans. Am. Soc. C. E., in the writer's discussion of a paper on "Lateral Earth Pressures."

In conclusion, then, the greatest necessity for the young engineer is, in my opinion to acquire the habit of logical analysis, and systematic combinaton, of the phenomena of nature, and in doing this, of course, to exercise every one of the manly qualities so well set out in Mr. Stern's paper.

DISCUSSION BY OTTO M. EIDLITZ

I have read Mr. Stern's article, "The Young Civil Engineer," and think that he has covered the subject thoroughly. From actual experience in the conduct of my own business there are a few points that might be amplified, although he clearly indicates them in his paper. Many a graduate of a technical school

---

Otto M. Eidlitz, New York City. Mr. Eidlitz is graduate of Cornell University in Civil Engineering of the class of 1881, and for many years has been at the head of the most thoroughly efficient firm of builders in that city.

is under the impression that if he has made his degree and received reasonable commendation from his instructors, the training he has imbibed at his college will be the means of immediate and permanent employment.

Although this might have been correct within limits fifteen or twenty years ago, it does not hold to-day, due to the fact that year by year the country is flooded with college graduates; so that to-day the personal equation counts as much, or more, than the work represented by the diploma.

The young engineer who enters an employment to-day must make up his mind that it is not so much his technical training which is of import, as it is his general efficiency, integrity, executive ability and above all, his desire to do as much work as a man can do.

There are few firms or corporations who will not, sooner or later, recognize the unselfish effort and devotion of the college man, provided he does not believe himself above the work allotted to him, and checks the tendency to lord it over any of his colleagues who may not have had his scholastic opportunities. When the opportunity arrives, he may reasonably expect advancement, but he must have patience to wait for it.

Many a man handicaps himself by not remaining long enough in one employment. If he is only seeking an opportunity to have his weekly salary increased, he very often sacrifices his chances for ultimate and permanent success to secure immediate pecuniary advancement. There are, of course, cases where the question of remuneration is crucial, and to that extent the individual in that condition is handicapped.

When the young engineer enters his career, whether professional or otherwise, he should be careful in the selection of his first or second employment, and then stick to it and show by his efforts that his whole aim and object in life is to give the best that is in him for the advancement of the interests of the employment with which he is associated. If he does this and has not an inflated idea of his own value, he will, within a reasonable time become of importance, and advancement will follow. He should not measure his efforts in hours, but let his employer appraise them by the results achieved. He should never forget that there are many abler men who are looking for his place and who are only prevented from securing it by the devotion and intensity of effort which the incumbent displays.

He should realize that a mistake may occur, but appreciate that most employers will condone it if it be frankly acknowledged, but that a concealment or prevarication surely spells disaster.

In short, a college training is of great value, but manhood is of vital importance and will frequently command greater respect and more immediate recognition than technical gifts.

DISCUSSION BY LOUIS L. BROWN

I have read with a great deal of interest Mr. Eugene W. Stern's article entitled "The Young Civil Engineer," appearing in the January issue of Applied Science.

There is no question about the vast importance to any young man entering the engineering profession of getting his start right. There is a great deal of practical experience, both in the office and in the shop and field, that is absolutely necessary for an engineer to have obtained in order to have a thorough grasp of his profession. This experience can only really be obtained while he is young and willing to stand for a great deal of knocking around, and to pitch in and work in very subordinate positions. I have known young engineers working as regular laborers on construction work.

No one can successfully direct and handle others until he has learnt by practical experience how it feels to be bossed.

Mr. Stern has covered the ground he attempted to in his article admirably and I might say exhaustively. Any young engineer starting out, who reads this article, and lives up to it, will certainly be heard from if he has any natural ability at all.

DISCUSSION BY T. H. ALISON

The writer has been requested to discuss the splendid paper "The Young Civil Engineer," by Mr. E. W. Stern. It certainly portrays necessary qualifications and their disposition in order to gain success by our young and old graduates in the engineering world. Many such characteristics are necessary to the success of an individual following any profession, but certain factors are especially required of a young civil engineer.

Advice has always been sought, sought of the more successful, but alas! it generally accomplishes little or nothing as it necessitates a perfect knowledge of the thought and conditions under which the seeker labors. Should a young man admire the personality, work and success of an older man, it is advisable that he draw out the latter in discussing his affairs and experiences. In this way many ideas are secured which may influence the younger man in determining what course he will follow. Frequently the young graduate has no particular inclination, in which case the sooner he secures any engineering position, the sooner he will find his natural bend.

Some are born bright and others acquire brightness by persistent plodding. All plod in the engineering profession, and

---

T. H. Alison, 149 Broadway, New York City. Mr. Alison is a graduate of the School of Practical Science of the class of 1892, and is chief engineer of the Augustus Smith Co.

L. L. Brown is a graduate of the School of Practical Science of the year 1895, and he is a thoroughly experienced civil engineer on construction, being associated with some of the most important erections of buildings in New York City.

whether or not one is naturally observant and inquisitive, it is essential that these two of many qualities be cultivated. Observation causes one to think, deduce and contrast. Whatever appears in the broad engineering world has been executed for a specific purpose. Whether it be well, reasonably or poorly rendered, it opens the channels of thought and from this one will deduce and contrast. Constant observation will stack a well stored mental library which cannot be taken away, and while books are indispensible, yet the truly cultivated, practical, observant, mind will far-out-act the book-worm and note-book faddist. It is well to remember that the minutest detail has its good purpose in a well designed article or structure. Observation is the best means towards improvement. As a leading graduate has said: "I never designed the same type of work twice without improving on the first, and when the second is finished I see how to improve again."

Inquisitiveness, the suppresser of pride, is not a failing in the young graduate. He is too prone to rely on the accrued theoretical knowledge gained at college. There is not a mechanic or laborer who cannot give practical reasons indispensable to the young graduate. Upon seeking advice of one of the leading engineers a graduate was told: "My boy, my only recommendation to you is to ask questions. Never turn your back on an open drain if there appears something of which you desire to be informed. Some of the best points I have gained have been from conversation with common laborers." Certainly the question of inquisitiveness can be carried too far, and a reasonable and common-sense degree only is advocated.

Mr. Stern's paper has outlined in a comprehensive and efficient manner the many characteristics of an ideal engineer. It is worthy of close attention, and as the graduates grow older, no doubt they will realize more forcibly the good sense therein contained.

No attempt has been made to criticise Mr. Stern's paper, but these two points appeal to the writer as being very essential.

Drive the nail "observation" home with the hammer "inquisitiveness."

DISCUSSION BY JAS. H. KENNEDY

Having read with considerable pleasure the admirable article of Mr. E. W. Stern in the January Applied Science, it has occurred to me that Mr. Stern has passed over too hastily the real question uppermost in the mind of the student as he is about to graduate from the college and, as the editor invites a discussion of the paper, I cannot resist the temptation to write for the benefit of a few, at least, of the students of our Alma Mater a few thoughts that it is hoped may be of use to them.

If memory serves me correctly, when I was leaving school

Jas. H. Kennedy—A graduate of the School of Practical Science, '82. He is Asst. Chief Engineer of the Vancouver, Victoria & Eastern Railway & Navigation Co.

the question was not so much "What shall I do next?" as "Shall I find anything to do?" and, judging from the number of applications for employment received every spring for several years back, not only from graduates of our Alma Mater but from many other colleges, a great many others have been face to face with the same momentous question, and it will ever be so.

To the young graduate the matter of seeking his first employment is the event of his lifetime, and a little wholesome advice at this point of his career from one who has not only been through the mill and written many applications, but has been the recipient of a fair share of the letters of not only students of our Alma Mater, but of many other colleges, may be a benefit to him. It is a fact that there are but few young graduates or undergraduates who know how to write a letter to an entire stranger asking for employment and, in making this statement, it is not insinuated that Toronto students are any greater sinners in that respect than those of other colleges and schools. The matter of writing a letter making application for employment is of considerably more importance than the average student has any idea of. Many a young fellow upon learning of a probable chance of employment, dashes off a few lines carelessly as if the whole world were waiting for him to get it done, never thinking of correcting his writing or perhaps his spelling, signs it with a flourish and addresses it to an entire stranger with the hope of receiving a favorable reply. Now, I have received many such letters and it may be interesting to some of the boys to hear what becomes of their letters. Of course they are all placed on file for future reference. Strangers are seldom employed while a worthy known young man is available. This fact of itself is generally a hardship upon the worthy student leaving college, but assuming there are no available known men when the staff is to be increased, the file of applications is taken down and letters compared. My advice to a young graduate, if he feels he should make application to a stranger for employment would be to make it his very best effort, give it his very best thought, express his meaning clearly, and in a business like way without flourishes or half written words, and sign his name in a way so there will be no mistaking it. In other words write a letter that will show up to advantage among a hundred others, or do not write at all. What chance has a man who dashes off a signature that requires the aid of the whole office staff to decipher it? Many letters are received that the contents can be easily read but the signatures are incomprehensible and they are consigned to the waste paper basket. Other things being equal the man who writes carefully and with all details accurate will be considered careful in matters of detail, and will be likely to succeed while a slipshod writer will be rejected on account of the fear of slipshod work. Nor should he resort to typewriting instead of showing up his handwriting. Many make this mistake. In order to succeed it is is not only necessary for the application to be on file when a vacancy occurs, but there must be something in that letter to lead to the expectation that the writer is in some way superior to the writers of the other letters; and there must be no available known worthy man in sight for the vacancy. Consequently the chances of securing employment by written application at best are not at all encouraging; but sometimes do succeed. In this connection if a personal reference be excusable the writer has on many occasions, when temporarily out of employment, written, asking for employment, but not in a single instance was a situation ever obtained by a written application to an entire stranger. Possibly nobody succeeded in reading the signature; but on the other hand, in the last few years, of the several hundreds of applications received from other unfortunates, possibly not more than twenty were successful, which is but a small percentage of the total men employed; and that at a time when there seemed to be work for everybody.

To the graduate especially who wishes to take up railway work, if possible for him to do so, the writer's advice would be instead of writing letters and awaiting replies, to go personally to where work is in progress, and be on the ground when the vacancy occurs. Drop into the first opening that offers, whatever it may be, and thus he will form acquaintances among the men who are doing things, and in this way he will work upward. Strive to make up one job lead up to another, as it almost invariably does to the man who does his work well; and no man who does his work better than his fellow workers will wait very long for an opportunity to move upwards. If he does the fault will probably be in himself.

DISCUSSION OF T. KENNARD THOMSON.

It is with much pleasure that I accede to the request to discuss Mr. Stern's well written paper on what a young engineer should do.

There is a very brilliant Canadian girl in New York, the sister of an old classmate of mine and a member of a very brilliant Canadian family, who now, in one of the New York dailies, answers letters from young people seeking advice. Her counsel is always good and to the point—but she says that people do not want advice, they merely want you to agree with them. So whenever possible she tells them what she thinks they want. This reminds me of a story they tell of Roosevelt (whether it is true or not I do not know) to the effect that he on one occasion asked an old lawyer friend to make a report for him. His friend said: "Why don't you ask one of your cabinet since you have a number of the brightest lawyers in the country around you?"

T. Kennard Thomson, New York City. Mr. Thomson is a graduate of the School of Practical Science in Civil Engineering of the class of 1886. His wide experience qualifies him to make an authoritative criticism.

Roosevelt is said to have answered: "I have, but they don't agree with me on the subject."

As Mr. Stern has written on what a young man should do, I will take the liberty of writing more of my personal experience and try to give some of the advice I received as I went along and by which I tried to profit.

Before graduating in '86 I spent three summers on the Canadian Pacific Railway, starting at Medicine Hat on the South Saskatchewan River and finishing in the Selkirks. The first two seasons were spent in the bridge department under a very able engineer, Mr. W. A. Doane. Very shortly after starting, on seeing in a Toronto paper, a very inaccurately written article concerning the western country I wrote a letter to the Toronto Globe, giving my impressions and asking what they would pay for similar ones. I was delighted to get a prompt answer offering me $4 a column for all I could send them, so I sent all I could during my three summers there. About this time an old gentleman of whom I thought a great deal, said: "First, write enough to fill a book, and then boil it down to a chapter, and then if possible, condense the information to one page. In other words, cultivate brevity and simplicity. This desideratum should apply to speakers as well as to written language.

During the summer prior to graduation, I succeeded in having myself transferred from the bridge department to the field so that I obtained experience in every branch of railroad location and construction. By working every night I was able to fill two good sized note books with the designs of all the wooden bridges used on that section of the C. P. R. These notes were used as vacation work at college and have since been instrumental in securing or helping to secure several jobs in addition to netting me $75 from a periodical which published a few of them. During the first two summers my pay was $50 a month and expenses. This was raised to $75 per month and expenses for the third summer.

On finishing my work in '85 in the Selkirks I seized the opportunity to take a trip to San Francisco and back, although it made me late in getting back to college. I started by walking the "gap," 90 miles in three days, thence by rail and steamer to that beautiful "English" city of Victoria and by boat to San Francisco. I returned by the same route. As a rule, however, whenever I had to go to the same place on different occasions an effort was made to go by different routes in order to see as much of the country as possible. This enabled me to see Detroit, Chicago, Milwaukee, St. Paul, Minneapolis and Winnipeg before graduating. I had also visited the "Sault" and sailed the Great Lakes. As I was fortunate in those days in seeing a great deal of Mr. James Ross, then manager of construction, an opportunity was taken to ask him if he considered a course in a European university would be advisable after leaving the School of Practical Science. He said: "I used to work on the same road as your Principal Galbraith. He is a good engineer and a brainy man and an engineer should not need any more university training after he turns him out. On the other hand, if you can afford to travel in Europe for perhaps a year, it will be very valuable." This I was unable to do.

About this time an old friend said: "Young man, when you get a position never worry your head about being 'fired,' but do your work in such a way that your employer will be afraid that you will get a better offer from some one else." It has often been said that we learn more from mistakes than from successes and this sage remark suggested to me the wisdom of trying to learn from the other man's mistakes instead of waiting for one's own. There is always an inclination to copy the big men, but while one can always gain much by studying such men, to try to "ape" or copy them will be ruin or dismal failure. For instance, our Duggan, who graduated three years before me and under whom I worked for two years after graduating, is one whom I would have copied if I had not convinced myself that every one has to work out his own individual path to success and follow it in his own way, taking advantage of every legitimate help or assistance that he meets on the road.

Anything that is not worth doing well is not worth doing at all and anything that is done well pays—even if it is only sweeping out an office or playing a game of football. Be accurate first, and then turn out as much work as possible. But, as Mr. Stern has intimated, don't make a calculation to six places of decimals when a hundred or even a thousand pounds or dollars would not affect the result. An illustration or two will show what I mean. An engineer once made a survey of several acres, taking an immense number of levels, every reading being to two places of decimals. After he had calculated the cubic contents required to fill this area to a certain height, having used the two places of decimals throughout, he estimated that as the ground was soft he had better add 12 inches to the depth to be filled. A military gentleman once paced the circumference of a circle and then calculated the diameter to six decimal points. Having known Duggan for some years as he was on the C. P. R. the second and third summers that I was west, I wrote him at the Dominion Bridge Company in the spring of '86 and, thanks to him, obtained the day after I was graduated a position in that concern at $40 a month. In six weeks or so after working as hard as possible and being convinced that my chief was satisfied with my work, I struck for $50 and got it, and about September of the same year got $60.

There is no work that a man can do that teaches accuracy quite as well as the making of drawings in a bridge company's office. Every engineer would be benefitted by such an experience. Every engineer should be able to handle surveying instruments and be able to make good plain drawings. Even now I occasionally go back to the drawing board myself and have been paid $50 or more a day by former employers for making drawings for them for special purposes. This is mentioned because many young men think that they will soon be too big to make drawings themselves and do not take the trouble to become proficient.

While I was getting $60 a month at Lachine, I was offered $100 a month and expenses as resident engineer on a Western railroad, but feeling that I knew enough about that work for the time, and not enough about bridge designing, I refused it. About fifteen months after graduating I asked for $75. This the President of the company told the Chief Engineer he would not pay, as he could get all the men he wanted for $50. He was then paying me $60. I forthwith requested a permanent leave of absence which, after considerable discussion, was withdrawn on condition of a two weeks' vacation being thrown in with the $75 a month. It might be stated here that during my last year at college I had met a Toronto girl whom I made up my mind almost at first sight to marry if I could. I took this vacation to win her consent. Being so fortunate in this respect myself, my strong belief in early marriages (24 or 25) has increased.

Two years at the Dominion Bridge Company which experience included the making of blue prints, tracings, shop drawings, show drawings, bills of material, shipping bills, etc., and the spending of much time in the shop, seemed sufficient, especially as I was in a hurry to get married. I gave up my position and came to New York on "spec," and in four days struck a job in the Pencoyd Bridge Company through calling and introducing myself to Mr. C. C. Schneider, chief engineer, who then had an office in New York and who has done much for me since. I was married that fall, and decided to settle in Philadelphia for some years. The next spring, however, we thought it would be a good scheme to attend the convention of the American Society of Civil Engineers at the Paris Exposition. Not being able to obtain leave of absence it was necessary to resign my position. A glance at the salary diagram will show that nothing was lost by this, for by a curious streak of luck my old company was hard up for men when we returned. I had tried unsuccessfully to get a job in Montreal, Toronto, Detroit and New York.

We have never regretted the four months thus spent in Europe. We again settled down "for years" but in January my first chief, Mr. Doane of the Rockies, offered the position of Bridge Engineer of the Ohio Extension of the Norfolk & Western R. R. at a salary of $150 a month. The Bridge Company, which had raised the salary every time another bridge company made me an offer—one of which came from Duggan—was only too glad to have a believer of Pencoyd secure such a position, and let me go. This position gave me experience in the design and construction of 129 bridges, requiring frequent trips to the most important bridge shops in the country. It was held for one and a half years, until an offer of $200 was obtained with a consulting engineer in New York. After about two years with him, going on the assumption that one can get almost as much for half his time as for the whole of it, I obtained the position of Chief Engineer of one of the best foundation contractors in the country with the privilege of handling all the outside work I could get. This I held for eight years, while working up a good consulting practice.

Naturally, I am grateful for the advice Dean Galbraith gave us on graduating: "Spend ten years getting as great a variety of work or experience as possible and see as much of the country as you can. It has seemed to me that it is nearly always desirable to obtain the largest salary possible on the principle that the employer is going to give the best work to the highest paid men. The most effectual way to obtain an increase in salary after one has made his value felt is to obtain a better offer from some one else. But one who threatens to leave if he does not get a raise and then stays after being refused has given himself a very black eye. Never give your employer a chance to tell you to work harder or longer. In emergencies don't count the hours. I have been 86 hours on a stretch on my feet. As a regular thing an employer is foolish to work his men more than eight hours a day, but in special cases the clock should not be considered.

If you want to get there—whenever you feel that you are losing interest in your work, get out and kick yourself before your employer gets on to you and don't get into a rut. Nothing that is easy to obtain is worth having. One of the most pitiful sights is to see a square peg in a round hole. I knew a beautiful draftsman who was absolutely wanting in the originality essential in an engineer, whose pay after a certain time kept decreasing as well as the quality of his work. He would have made a success on the stage. Another man made a failure as a clerk where he would have been a genius in another line. There was a brilliant chess player who plodded along on a drafting board where he did not belong. There are mighty few industrious, intelligent men who would not obtain great success in some line if they only had the courage to find out what it is and drop what thy are doing.

An old faithful employee, who had fallen into a rut, once went to the head of the firm with whom he had grown old, and bitterly complained that a younger man had been put over him. The employer said: "Mr. Jones see what is making that noise." Jones went to the next room and in a few minutes returned with the information that there was a big crowd in the street. See what the crowd is doing." Jones came back and said: "They are watching a lot of cattle." "See where the cattle are going." Jones came back and reported: "South." "See how many there are." Jones came back with the approximate number. The employer then asked Jones to sit down while he rang for the young man, to whom he said: "Brown, see what that noise is about." In a few minutes Brown came back and reported: "There is a big crowd of people in the street watching 500 head of cattle which Swift & Co., have sent from Chicago to Jackson & Co. at the other end of the street." The young man retired and the employer kindly turned to his old employee and said: "You see, my friend, why the wide-awake man gets ahead."

But enough of this or your good editor will get so tired that he will throw the whole discussion into the fire. As it is, I must rely on him to blue pencil what he considers of no interest to you, or otherwise objectionable.

ALUMINIUM

J. A. McKENZIE WILLIAMS, '09

The present state of the metal market displays an unprecedented condition as regards aluminium.

This metal is now produced in such enormous quantities, compared with the production of a few years since, and the time of expiration of the American patents is drawing so close (Feb. 1909), that the different producers in operation at present are beginning the competitive struggle which has been so notable for its absence during the preceding years.

The range of quotations since Dec. 1907, has been from 42c to 13½c per pound, this latter figure being one of the late quotations in the British market. At the beginning of the year 1908 there was a notable decline in the British market from 33c to 22c. and a corresponding decline in the American market from 38c to 33c.

The American producers have always followed the railroad procedure of "charging all the traffic would bear," and in addition to this have been, and still are, protected by a tariff of 8c. per pound which effectively prevents imports of aluminium from foreign markets, and which keeps the quotations at least 8c higher than European prices.

In Britain and the Continent the various companies were until recently producing under license from patentees, and by establishing an "understanding" were able to prevent any disturbance of the market, and maintain high prices until about the 30th of Sept. of this year when this arrangement terminated, and the free competition began which has so speedily given us the satisfaction of seeing aluminium take rank with the old staples, copper, zinc, tin, etc.

Weight for weight, aluminium is now cheaper than zinc, and bulk for bulk, cheaper than copper at a market of, say, 25c.

It is probable that careful calculation will show the cost of production in America to be about 15c, and in Europe about 17½c on the average, and the present quotation of 13½c cannot be expected to last long. However, the fact remains that aluminium has become one of the staple metals at last, and that from the present division of the price by about two, an enormously stimulated consumption may be expected. In anticipation of this, the present producers in America, Britain and elsewhere are extending their plants by doubling and trebling their present capacities.

An instance of this may be cited, the increased capacity of the various plants of the Pittsburg Reduction Co., which company was using in

	1906	1907
At Niagara, N.Y.	12,000	40,000
Massena, N.Y.	12,000	20,000
Shawenegan Falls (Que.)	5,000	15,000
Or a total horsepower of	29,000	75,000

This total capacity should give a total production of 36,000,000 lbs for the continent, of which Canada could produce about 10,000,000 lbs.

This same company has also doubled the capacity of its rolling mills at New Kensington, Penn., and is erecting one at Niagara Falls, which will have two-thirds of the capacity of the New Kensington mills. These New Kensington mills are, by the way, the only ones in America producing continuous sheets of aluminium.

In Europe there were only four companies in operation in 1907, but it is probable that there have been many additions during 1908. The total estimated capacities of these four companies in 1908, in terms of horsepower used, is

British	75,000
French	27,500
German	75,000

having a total of 177,500 H.P., and since 4 H.P. years produce 2,290 lbs. they have a possible production of about 101,400,000 lbs., working at full load.

A comparison of the production at various periods is also very interesting, and to avoid too many figures, production is given for periods about three years apart.

U. S. A. PRODUCTION

	Lbs.	Value	Per lb.
1897	4,000,000	$ 1,400,000	35c.
1900	7,150,000	2,288,000	32c.
1904	7,700,000	2,233,000	29c.
1907	26,000,000	10,000,000	42c.

WORLD PRODUCTION.

	Lbs.
1897	6,390,000
1900	14,678,000
1904	16,246,000
1907	65,058,000

So great is the present demand that it may be confidently predicted that the output will surpass 200,000,000 lbs in 5 years, and that by the end of 1908, the production will make a significant showing in comparison with copper, taking into account the relative bulks of the two metals.

On account of the present and prospective importance of aluminium, it is interesting to review briefly the past history of the development of the metallurgy of aluminium, and to glance at some of its present uses.

After a century of struggle, investigation and invention, the problem of extraction of this widely distributed element, aluminium, from some of its compounds was finally worked out to a commercial basis. Many processes were devised and suggested, some impossible, some impracticable, and some workable, but ruled out on account of their high cost. Finally from the many, two only survive the test of commercial application, that of Charles M. Hall, of the United States, and that of Paul L. Heroult, of France, and which processes are practically identical.

The various methods of producing aluminium may be classified under one of the three following heads:—

(1) CHEMICAL METHODS.

(2) ELECTRICAL METHODS (Electrical, as distinguished from Electrolytic, i.e., methods which utilize the heating effect only, and which could be carried out by other methods provided the necessary temperature could be attained).

(3) ELECTROLYTIC METHODS:—i.e., methods making use of the chemical effects of the passage of a current of electricity. For example, a common electrolytic process is the passage of a current of electricity through a solution of, say, copper sulphate, as in refining copper. The current enters the solution by a copper electrode, called the anode, passes through the solution of copper sulphate, which is decomposed thereby and is the electrolyte or bath and then out by a second electrode of copper which is called the cathode.

(1) CHEMICAL METHODS—(Running over the principal methods rapidly).

In 1827 Wohler was successful in reducing the anhydrous chloride of aluminium by means of potassium.

In 1855 St. Claire-Deville simplified the method of Wohler by using the double chloride of aluminium and sodium — Al_2Cl_64NaCl, and using the metallic sodium which was much cheaper than the metallic potassium. This process was conducted in France for the production of aluminium for 30 years, and was finally abandoned on account of the high cost of the sodium and the aluminium chloride, and the successful production by other methods.

In 1855 Rose had proposed the use of the mineral cryolite, i.e., $Al_2F_6.6NaF$, instead of the simple chloride, but this was not followed till 1886, when Grabau, a German, devised another practical process to use the cryolite. In this interesting process, sulphate of aluminium was treated with cryolite, and the sodium fluoride of the cryolite reacted with the aluminium sulphate, and aluminium fluoride was formed. Thus the aluminium was all obtained in the form of the fluoride according to the equation:—

$$Al_2(SO_4)_3 + \underbrace{Al_2F_6.6NaF}_{\text{Cryolite.}} = 2Al_2F_6 + 3Na_2SO_4$$

The fluoride, which is insoluble in water, was separated, dried and heated to redness, and charged into a cold vessel lined with cryolite. The proper amount of sodium to exactly react with this fluoride, and in the form of a cube or cylinder, was now placed on the hot mass, and the whole immediately covered. A quiet action, but accompanied with great heat, then took place, which resulted in metallic aluminium, and the reproduction of an artificial cryolite according to the equation.

$$2Al_2F_6 + 3Na_2 = Al_2 + Al_2F_6.6NaF$$

The metal was found at the bottom of the mass, which was completely fused by the intense heat. The by-product could again be used for the production of the fresh fluoride Al_2F_6.

This process had the great advantage that it produced exceptionally pure aluminium, and of all chemical methods, it seems the only one which is at all likely to come into competition with electro-chemical methods, and depends essentially on a cheap sodium.

2. ELECTRICAL METHODS.

During the advances along purely chemical lines, experiments were also taking place in which electric current was playing a part, but it was not until the dynamo was invented in 1867 that any of these methods assumed a practical importance.

In 1862, Moncton had taken out a patent in England for a process in which he intended to pass a strong electrical current through a reduction chamber charged with alumina Al_2O_3 and granulated carbon, the reduction taking place by means of the carbon which was heated to the high temperature required, by the current. This at the time was not practicable on account of the cost of the current, and also because the aluminium produced absorbed so much of the carbon that the product was a grey, brittle, crumbling mass, scarcely fused, and containing carbides, carbon, and impurities present in the carbon used. Much aluminium was also carried off in the vapors, and some condensed in the upper layers of carbon.

It was not until 1884 that another electrical process, similar to above in principle, was applied, but now with greater success. This was the Cowles process, invented by the Cowles Bros. in an experimental plant at Cleveland, Ohio, and consisted essentially of passing an electric current through granulated material of high resistance, i.e., low electrical conductivity. In consequence of this high resistance, it became red hot, and afforded all the heat required. The substance to be reduced was mixed with this granular material and thus absorbed the heat at the very place of its production.

It is seen that so far Cowles' scheme was identical with that of Moncton, but taking it for granted that satisfactory aluminum could not be so produced, they devoted their attention to the production of alloys, which on account of the high cost of pure aluminium at the time, were more generally used.

This is the key to their great success as it gave aluminum, in the form of its greatly used alloys, at a sixth of the former prices.

To accomplish this, Cowles used the mixture of Moncton, i.e., granulated carbon, alumina, to which he added granulated copper, thus, the aluminium, as soon as produced, formed an alloy with copper, and after the run, was found as a fused mass below.

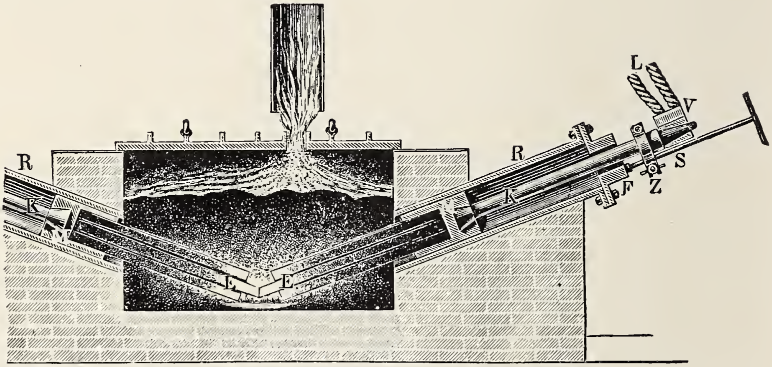


Fig. 1

After a two hours' run, he obtained 5 lbs. of an alloy, aluminium bronze, which contained 15 to 20 per cent. of aluminium. Now by substituting this alloy, instead of copper, in the next run an alloy was obtained containing over 30 per cent aluminium. On this success, the Cowles Co. later re-organized as the Cowles Electric, Smelting & Refining Co., started their works at Lockport, N. Y., and began the production of alloys, not only of aluminium, but using the same principle they produced silicon bronze, boron bronze, and many others of practical importance. Fig. 1 illustrates the principle.

3. ELECTROLYTIC METHODS.

Now looking at the electrolytic methods, we find that in this field also there were hosts of suggestions and methods tried for the production of aluminium from aqueous solutions of various aluminium salts, but none with success. However, when the salts alone were used and electrolyzed, the production was successful.

Among the earliest attempts, was that of Davy. He had just succeeded by his classical experiments of 1807 and 1808 in producing potassium and sodium from the fused hydroxides. He also attempted to produce aluminium by the electrolytic decomposition of Al_2O_3 alumina, but was unsuccessful. However, he achieved a measure of success when he coated a sheet of platinum, used as a positive electrode or anode, with a paste of moistened alumina, and buried in the mass the end of an iron wire as a cathode. To these two electrodes he connected a voltaic battery of 1,000 cells. On making the connection, the wire was instantly heated to a white heat, and fused at the point of contact with the alumina paste. The metallic mass, after cooling, was both whiter and more brittle than the iron, and on dissolving in acid, a solution was obtained from which alumina could readily be separated—thus Davy had prepared the first alloy of iron and aluminium.

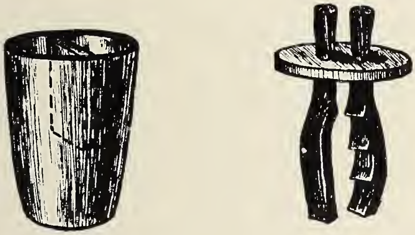


Fig. 2

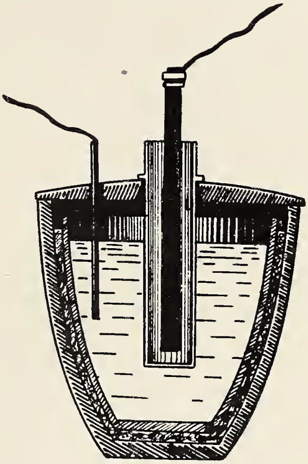


Fig. 3

However, it was not until 1854 that the electrolytic production of pure aluminium was first accomplished by Prof. Bunsen, of Heidelburg, who had already produced barium, chromium and manganese. This he accomplished by the same apparatus (Fig. 2) which he had used for production of magnesium, which consists simply of a small crucible in which two small flattened and grooved carbon electrodes were dipped. The compound used was placed in the crucible and fused, the electrodes dipped in, and the current passed through—the metal produced being caught in the grooves. The apparatus was then cooled, and the solidified mass broken and the metal obtained.

St. Claire-Deville, after hearing of Bunsen's previous brilliant successes with chromium, manganese, barium, etc., had meanwhile been applying these methods towards the production of aluminium, and this led to the almost simultaneous discoveries by Bunsen and himself of the same method of preparation. Bunsen had, however, published his account in July, 1854, though St. Claire-Deville succeeded him by only a few weeks in August. St. Claire-Deville had modified the apparatus somewhat, (Fig. 3) and found in addition that Al_2Cl_6 could not be used as it volatilized at a low temperature, but found that the double chloride of aluminium and sodium worked well, and was fusible at a comparatively low temperature (186° C).

In carrying out the electrolysis, he gradually increased the temperature of the crucible to a point just below the melting point of aluminium, the current was passed through from the time of fusion, and continued with a gradual increase in temperature till just below the melting point of the aluminium. Now the current was stopped by taking out the electrode, the temperature raised to bright redness, and then the crucible allowed to cool. Afterwards the aluminium was found at the bottom as a regulus.

St. Claire-Deville had exhibited some of his product in 1854 at the French Academy. It was contaminated with carbon from the electrodes, which prevented the formation of a clean button. He also proposed using an anode composed of alumina and carbon, which, as the production of the aluminium proceeded at the cathode, would make up this loss by dissolving.

Interesting as these experiments of Bunsen and St. Claire-Deville were, they were not applied, on account of some practical difficulties, but they at least proved that production from fused electrolytes was possible, and so laid the foundation for the present methods.

Some of the chief difficulties were that—

(1) The carbon electrodes were disintegrated rapidly. These are now made of far greater compactness, and are therefore quite satisfactory.

(2) The fused electrolyte and metal produced, attacked the containing vessel. If a clay crucible, the clay was partially reduced, and silicon freed, and thus contaminated the metal. Porcelain crucibles have these faults, and in addition are fragile and costly. Carbon crucibles were so porous and so much attacked that they could not be used unless protected on the outside with some other substance, and metallic crucibles were unsuitable because they were attacked, and the aluminium produced formed an alloy.

(3) No suitable substance is known for making crucibles for containing the fused Halogen salts which could be heated externally.

Hosts of others in the next 25 years obtained patents on various methods, and among them Henderson in England in a patent in 1886 approached closely to the modern methods, but was at fault in still clinging to the external heating.

The problem had awakened wide interest, and among the ranks of the investigators were found Charles M. Hall and Paul L. Heroult, then both students, both 23 years of age, now world-famed electro-metallurgists. Hall was taking a classical course at Oberlin College, Ohio, and graduated in 1885. During the course he had but one term of chemistry, which, however, so captivated him that he spent his next year in the Oberlin Laboratory with the special object of finding an electrical method of commercially producing aluminium. He used the common voltaic cells, and built up a battery, using a gasoline heater to fuse his electrolyte (Fig. 4).

His method of attack was to find a solvent for alumina which would fuse readily, and from this solution obtain aluminium by electrolysis. At first he was not successful, as his clay crucibles were destroyed by the fused salt, and it was only when he lined his crucibles with a mixture of tar and ground retort carbon that he was successful in getting a yield of metal. The solvent he used was cryolite, and he found, as is generally the case, that the mixture melted at a lower temperature than either the alumina (Al_2O_3) or cryolite alone.

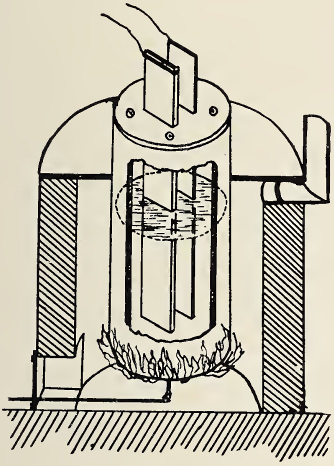


Fig. 4

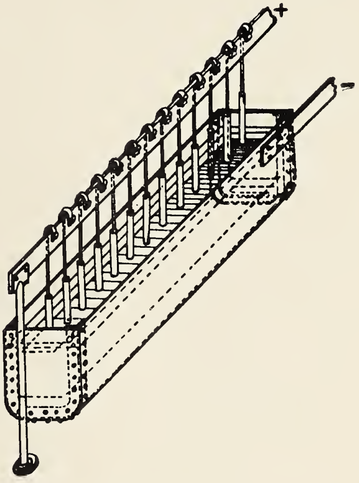


Fig. 5

He now went to Boston, raised money to continue experiments and rented power from a small dynamo for four months, and experimented with copper electrodes which, however, were unsatisfactory, and he finally concluded that by improving the carbon electrodes, they would be the most satisfactory of all electrodes, for commercial work.

In July, 1886, he applied for his first patent, the basic principle of which was using as a solvent the double fluoride of aluminium, and some more electropositive metal, in this case ($Al_2F_6.6NaF$) cryolite.

He now returned to Oberlin determined to devise a commercial method, and being without funds, had to content himself with making bichromate cells, and working with a small iron crucible, but the results so encouraged him that in December, 1886, he went to relatives in Cleveland in order to negotiate for funds.

Meanwhile Heroult had patented in France at almost the identical date, the same process, and now had applied for a patent in the United States, and, as Hall had not as yet produced aluminium commercially, the United States Patent Office declared an interference between Hall's and Heroult's application.

He was then forced to make an agreement with Cowles Electric Smelting & Aluminium Company, by which they took an option on the process in exchange for supplying power, and giving Hall an interest if successful.

At the expiration of the time, the Cowles Co. did not take up the option, so Hall, who had now some connection, formed the Pittsburg Reduction Co. in 1888. Meanwhile the interference at the Patent Office had been decided in Hall's favor.

Now, with sufficient funds, Hall went to work on a larger scale, and by so doing was successful. In 1891 the plant was moved to New Kensington, Penn., and in 1893 the Niagara Power Co., which was just starting and looking for consumers for their power, made the Reduction Company an attractive offer at $18 per H.P. a year. This they accepted, and started what is known as the "upper works," and being eminently successful, they added the "lower works" in 1896.

From this time the company has been continuously successful, and constantly increasing their capacity. They found that by increasing the size of the vessel, or cell, that the heat generated by the reaction maintained the temperature sufficiently to keep the bath in a state of fusion, and so they were saved the expense of external heating (Fig. 5).

They also soon found it necessary to purify the bauxite which they used as the source of alumina. This was accomplished by mixing it with enough carbon to reduce all the impurities such as silica, iron oxide and titanium oxide, to the metallic state, and then melting in an electric furnace. The reduced impurities formed an alloy, leaving the alumina above almost chemically pure. This alumina is granular, dissolves easily, and produces a metal of high purity.

Heroult, in 1900, described how he stumbled across his process. He was attempting to electrolyze cryolite $Al_2Fl_6.6NaF$ with an iron cathode and carbon anode, and had added some double chloride Al_2Cl_64NaCl, to make the mixture melt more easily. He obtained some aluminium alloy at the iron cathode, but observed no evolution of chlorine or fluorine at the anode, which was attacked, however, and yielded CO and CO_2. He therefore concluded that some oxide was present as an impurity. Following up this clue, he then added pure alumina Al_2O_3, and obtained only CO_2 and aluminium.

He immediately obtained a patent, and went to a manufacturer who was producing aluminium by the sodium process. This manufacturer advised him to turn his attention to alloys as the use of the pure metal was limited. This he did, but, after working a couple of years, he learned that Hall was now making pure aluminium successfully. He therefore started production, and placed some of his product on the market about a year after Hall had started commercial production, but it was not until 1890 that he was selling a grade equal to Hall's. Heroult also patented his process in England and on the continent, and production of aluminium was carried on by four companies using his patent under license. These patents nominally expired in 1901 but extension of time was applied for and it was not till 1907 that many outside plants were contemplated in Europe. In America it was not all smooth sailing with the Pittsburg Reduction Co. This company entered suit against the Cowles Co. in 1893, and obtained an injunction restraining the Cowles Co. from the manufacture of aluminium.

Meanwhile Charles S. Bradley a very noted electrial engineer, had patented the idea of internal heating. This patent was fought by the Cowles Co., who had, since the beginning, used internal heating in their production of aluminium alloys. The Cowles Co. won their suit, and now in turn, they fought the Pittsburg Reduction Co., which Company, as was mentioned before, had abandoned their external heating, when they found that the heat evolved by the reaction was sufficient to keep the bath fused. This suit they also won, and the Pittsburg Reduction Co. was compelled to pay heavy damages. As a result of these decisions, the process was tied up, the Cowles Electric Smelting & Refining Co. owning the internal heating part of the process, and the Pittsburg Reduction Co. the electrolysis of alumina in a bath of fused cryolite. Hence neither could work without the other, and, of course, this resulted in a practical amalgamation of interests, till February, 1909, when the Bradley patent expired and the whole process became public property.

The various uses to which aluminium is put, depend for the most part, upon its low Sp. G. 2.6, its relatively high conductivity, its white color, and to the fact that the oxide which forms in air is white, and forms a compact, coherent coating over the metal which is extremely thin, resistant to further oxidation, and therefore does not detract from the appearance of the metal.

Since the Sp. G. of aluminium is 2.6 and that of copper about 8.9, therefore a given weight of aluminium will occupy about four times as great a volume as the same weight of copper; therefore, if we represent a given weight of copper by a solid figure, then the volume of aluminium, being four times as great, would be represented by four similar figures having the same depth. Therefore, the upper surface of the aluminium would be four times that of the copper, of the same weight and depth, and now, since the conductivity of copper compared with that of aluminium, is as 1 to .6, and if we call the conductivity of the copper 1, then the conductivity of aluminum will be four times .6 = 2.4, or say, about twice that of the copper. These two considerations show that with aluminium at the same price as copper, for castings and all work where volume alone is concerned, aluminium would cost one-quarter as much as the same volume of copper, and where conductivity is concerned, since half the weight will give more than equal the conductivity, therefore, the cost would be about half that of copper.

Conductors of aluminium are now in extensive use in electrolytic works, and in electric furnace work where heavy currents at low voltage are required, some of these conductors being of great size, as for example, 2″x4″, 4″x4″, 2″x6″, and look like squared lumber. This use as conductors is not confined to large sizes. Power companies are using aluminium wires and cables, one, at least in Canada, being 90 miles in length. In the Western States aluminium wire is now greatly used, and iron wire coated with aluminium is used in place of the former galvanized products in telephone and telegraph work.

Soldering of aluminium has occasioned much difficulty on account of the film of oxide which rapidly forms on the surface, and prevents ordinary solders wetting the surface. No flux has yet been found which will dissolve this oxide and keep the metallic surface fresh long enough for ordinary soldering. To overcome this, numerous ways have been suggested, and each number of the various technical journals seems to add about as many more. Some claim to solder satisfactorily by using the untinned copper in such a way that it mechanically scratches the surface, i.e., by passing it backwards and forwards, and holding the solder against the copper while this is going on, thus the aluminium is mechanically cleared.

The Autogenous method is however probably the best, as no other metal takes part in the operation, a flux such as an alkali chloride being used, and the two surfaces to be united, pressed firmly together, and heated to a point just above the melting point of aluminium. The mechanical properties of such joints are good, and under the microscope present the same structure as aluminium itself. Sheets of aluminium 15mm. in thickness, and welded in this way have withstood 17 atmospheres. The process is useful, not only for welding wires and cables, but for aluminium apparatus, tubes, pipes, chemical apparatus, vessels, automobiles, etc. Pure aluminium is durable in sea water, but joints soldered with any other metal are attacked very readily.

Aluminium is now greatly employed as a pattern metal, it being light, easily finished with sandpaper and file.

The Wetherill zinc oxide furnace grate is cast in sand, moulded by an aluminium form. When wood was used, a great many small pieces were necessary, and with the aluminium it is all one piece, hence lessening the time and cost considerably.

Many aluminium objects are now prepared by a method similar to lead pipe, i.e., the metal is heated to a point just below melting, and squeezed out of forms continuously. In this way sheet aluminium of all gauges for automobile bodies, signs, cooking utensils, kodaks, etc., is produced. Some of the New York subway cars are lined with sheet aluminium, and the Japanese army was supplied with aluminium cooking utensils in the late war.

Aluminium pipe is also so produced, and is used for all sorts of purposes,—acetic acid plants, nitric acid condensors, in pulp mills, the finest pipe being used as needle indicators on various instruments, as in galvanometers, etc.

Rods of all sorts and shapes, from the enormous bus-bars to the finest thread-like wire for lace fabrics, mouldings of all patterns, and for various purposes are produced in this way.

Aluminium is now extensively used as a deoxidizer to produce sound castings, and many thousands of pounds are used annually for this purpose.

For plating on aluminium, no really satisfactory method yet exists by which one metal may be directly plated on aluminium; this is due to the ever present film of oxide, but it is said that by dipping first in a solution of stannous chloride and ammonium alum, a film of metallic tin coats the aluminium on which a deposit of other metals may then be satisfactorily plated.

ALLOYS

Among the chief alloys are aluminium bronze, consisting of aluminium and copper. These bronzes are greatly used in machine designs where lightness and strength must be combined, as in automobiles. They are also used for decorative work where a non-tarnishing yellow color is required. A new bronze, consisting of copper 39, iron 34, nickel 18, aluminium 9, is as hard as nickel-steel, is strong, very resistant to sea water, moist air, and acid water. Six parts added to 24 of yellow brass is said to make the brass equal in strength to the best bronze.

Aluminium and zinc alloys are also used in automobile works, alloys containing copper, aluminium, tin, and antimony for horse-shoeing, and many other alloys for special purposes are employed.

Respecting the tensile strength of some of these alloys, it is interesting to compare the tensile strength of some common products with aluminium bronze.

TENSILE STRENGTH

(Pounds per square inch)

Cast copper	24,000
Cast gun bronze	39,000
Steel plate rolled	81,000
Aluminium bronze castings	100,000
Aluminium bronze (with silicon)	130,000

Another important application of aluminium is in what are termed by the inventor, Dr. Goldschmidt, the aluminothermic reactions. When the oxides of such metals as titanium, iron, chromium, nickel, etc., are mixed with aluminium in a fine powder and some hot body applied, as a red hot iron rod, a vigorous reaction takes place by which the aluminium reduces the metallic oxide and leaves the metal in the free state. The aluminium is itself oxidized to the form of Al_2O_3, and floats on top as a slag.

This principle has been of great importance for the preparation of pure metals free from carbon. A mixture of iron oxide, Fe_2O_3, and aluminium powder is now on the market as Thermit, and finds extensive application in rail-welding and repairing broken castings of all kinds. The Russian army was supplied with Thermit for repairing their heavy ordnance, etc., during the war.

The application is a very simple matter, the greatest time being consumed in preparing the mould around the object to be repaired or welded. A conical shaped crucible is filled with Thermit mixture, a little barium peroxide added to the top, and in this a short piece of magnesium wire is placed. The crucible has an opening at the bottom, which is placed directly over the mould, and which may be opened or closed at the will of the operator. When everything is ready, the magnesium wire is lighted, and the heat soon liberates oxygen from the barium peroxide, which, uniting with the aluminium, starts the rest of the mixture reacting by the heat communicated. After a moment the vent is opened, and the molten metal allowed to flow into the mould. The heat of the reaction is so excessive that the metal it comes in contact with is soon heated to such an extent that a perfect union results.

There are still a great many other applications of aluminium which time prevents mentioning, while the near future is bound to see a great extension in the practical and every-day uses of aluminium.

N.B.—Read at a special meeting of the Chemical and Mining Section held on December 16th, 1908.

WATER METERS.

J. J. TRAILL, B.A.Sc.

Water meters may be defined as instruments by which the quantity of water flowing in a pipe is measured and the amount passed is recorded automatically. The number of meters devised is legion, if one may draw definite conclusions from patent office records, the British patent office records showing that for one period of ten years there were granted 389 patents of water meters or parts thereof. No perfect meter has been devised as yet, but this is not otherwise than should be expected, for the variety of service to which they are put is so great that most meters are designed to serve well in a few classes of work, while they may be entirely useless in other classes.

The important desiderata of a perfect meter are as follows: It should accurately measure all flows, whether fine or full; should work at very slight pressure; should work at high pressure without shock or water-hammer; should be small in bulk and easy to set and repair; should not be liable to "stick up" or stop, and when not registering when water is being passed through it should give some outward indication of the fact; and, finally, should be incapable of passing water backwards.

Meters are of two kinds, viz.: Positive and Inferential. Each of these classes may be subdivided. Positive meters measure the actual volume of the water by the action of a piston working in a cylinder which is successively emptied and filled at the completion of each stroke. The cylinder being of known dimensions affords a measure of the quantity of water discharged in a given interval of time. Inferential meters measure the velocity of the flowing water, generally by recording the revolutions of a turbine or other water wheel or, in the case of the Venturi meter, the pressure on a gauge.

Nearly all positive meters are included in the following four classes: Single cylinder reciprocating piston meters, double cylinder reciprocating piston meters, rotary piston meters (including the disc meters) and diaphragm meters.

The Kennedy meter shown in figures 1 and 2 is of the single cylinder reciprocating piston type. This meter will register the flow accurately even when so small a quantity as a drop at a time is being discharged. It is very bulky considering the quantity it will discharge, and is not, therefore, used to any extent as a domestic service meter. Its accuracy is such as to recommend it as a test meter and it is often used for this purpose, the meter to be tested being put in series with it, water run through and simultaneous readings taken on the two dials. The meter consists essentially of a cylinder and piston, a two-way cock, a tumbling weight to operate the cock and a dial on which the discharge is registered. Fig. 1. shows a section of the inlet and outlet pipes and the cock; Fig. 2, a side section of cylinder and piston inlet and outlet pipes and cock. The packing of the piston consists of a ring of very pure soft rubber, shown between the piston and walls of the cylinder. As the piston rises water flows into the bottom of the cylinder, filling it; the rack on the piston rod raises the weight by means of the pinion to which the latter is attached, until, when the end of the stroke is reached, the rack passes beyond the pinion, the weight falls, reversing the cock and the piston commences the return stroke. Any error which might occur through short stroking is made inef-

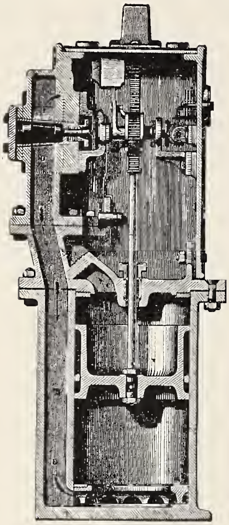


Fig. 1

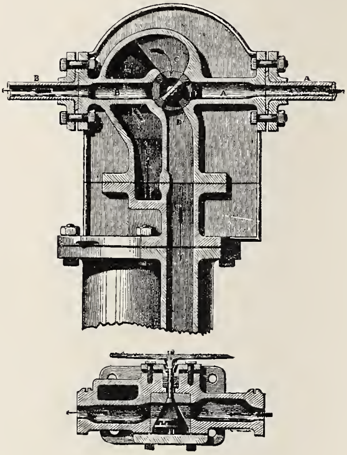


Fig. 2

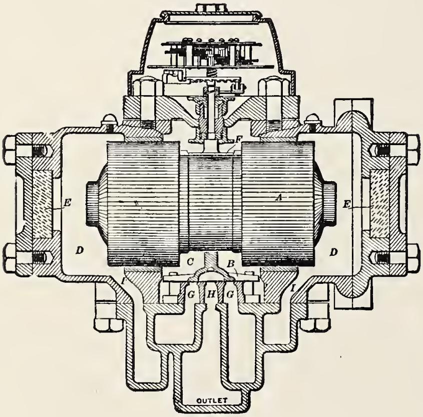


Fig. 3.

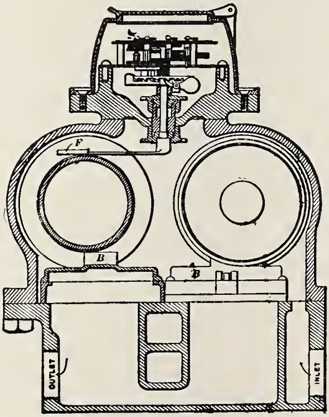


Fig. 4.

fective by having the counting gear record the distance travelled by the piston. With this meter there is danger of water-hammer if the piston speed becomes high.

Much more compact instruments are the double cylinder reciprocating piston meters. In these one piston actuates the valves of the other cylinder. The cylinders may be the same or different in size. Figures 3 and 4 show sections of a Worthington double cylinder meter in which both pistons are of the same size. Water flows into the cylinder under pressure from the main, displacing the piston, which, in turn, displaces the water in the other end of the cylinder, this flowing through the outlet port of the valve to the services pipes. Thus the plunger in moving displaces a fixed volume of water, discharging it through the outlet. The arrangement is such that the stroke of the two plungers alternates, the valve actuated by one admitting water behind the other. The plungers come to rest when they reach the rubber buffers at the ends of the cylinders. One plunger imparts a reciprocating motion to the lever F, which operates the counter movement through a spindle and ratchet gear. With this meter, which is otherwise a very accurate and reliable instrument, there is a danger of over-registration at fine flows through a tendency to short stroke.

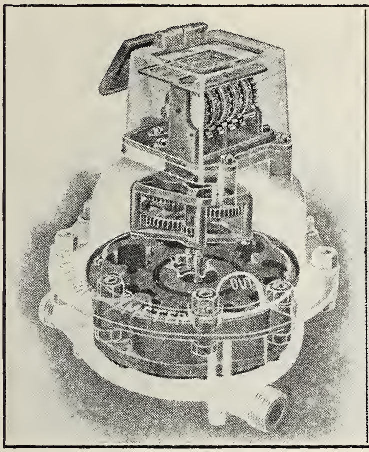


Fig. 5

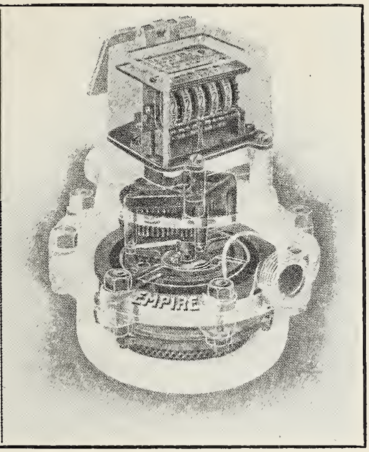


Fig. 6

Rotary piston and disc meters, engravings of which are shown in Figures 5, 6 and 7, are the next in the scale of accuracy where considerable variation in the flow is to be expected. These meters are easily kept in order, there being no valves, and, with the exception of the counting gear and piston or disc, no moving parts. The piston or disc in these meters is usually made of hard vulcanite with a specific gravity, nearly unity, the advantage being a slight reduction in friction. The pistons are of various shapes, generally complicated, but the action of all meters of either class—rotary piston or disc—is essentially the same for the class.

In the rotary piston meters the action is as follows: The centre of the piston has a circular motion, the lobes working in the small chambers of the cylinder, and these alternately cover and uncover the inlet and outlet ports of each chamber. The amount of water passed per revolution is equal to the difference in volume of the cylinder and piston. In these meters provision is made for a small amount of water to pass when, through accident, the piston becomes "stuck up." This is necessary in domestic supply meters, as the meter should not cut off the supply completely, but if not registering should give some decided indication of the fact.

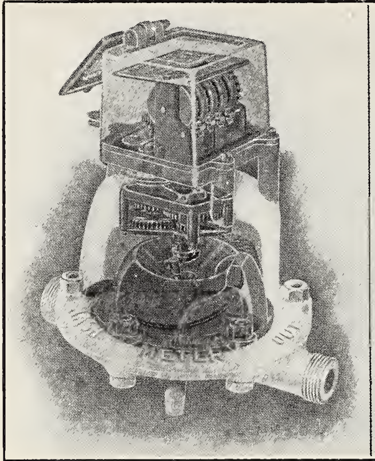


Fig. 7

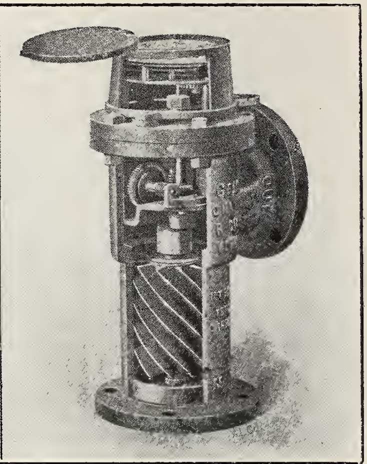


Fig. 8

The meter illustrated in Figure 6 is, as it were, a transition from the rotary piston to the disc type. There is, as in the rotary piston meter, a piston, but the arrangement of inlet and outlet ports is exactly similar to that of the disc meter.

In the disc meter shown in Figure 7, a disc with the shape of a flat cone "wabbles" back and forward in such a way that one element of the cone is always in contact with the chamber in which the disc works, thus shutting off free flow from the inlet to the outlet ports. The volume of water passed per revolution is, of course, fixed by the size of the chamber.

Rotary piston and disc meters are in use to a very large extent in America for metering domestic supply. In one instance a city in one of the northern states placed an order for 15.000 disc meters at one time. Both classes are fairly accurate over quite a wide range of flow. The life of the rotary piston meter is longer than the life of the disc meter. It is possible also by a simple repair to take up the wear of the piston for the former, but when the disc and disc chamber of the disc meter become worn the meter's usefulness is ended.

Diaphragm meters are not used to any great extent for water measurement. The meter consists of a pulsating diaphragm, in a vessel of known capacity, which is moved as the side chambers are alternately filled and emptied. The common dry gas meter is essentially a diaphragm meter.

Coming to the second general class, Inferential meters, we have first of all rotary turbine meters, a good type of this meter is shown in Fig. 8. By a comparison of the supply pipe of this meter with that of any of the positive meters it is immediately evident what a great saving in size—and hence in cost—is obtained by using a meter of this kind. The saving is at the expense of accuracy of registration at fine flow, meters of that kind being accurate only for medium or full flows. The action of the meter is evident from the figure.

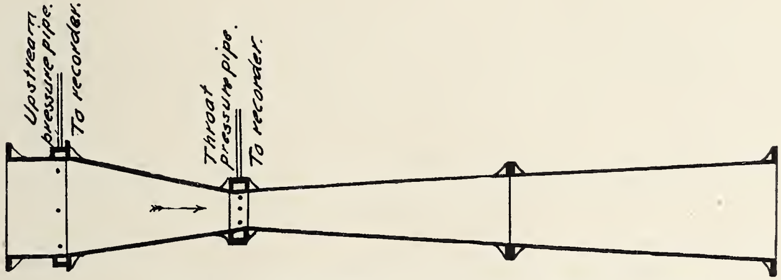


Fig. 9. Longitudinal section of Venturi Meter

Rotary fan meters are similar in principle to the ordinary windmill.

The Venturi meter might also be classed as an inferential meter. Briefly, the method of measurement of water by this meter is based on the fact, that when water flows through a pipe of which the section is gradually contracted and subsequently gradually increased, the pressure in the smallest section is much less than in the largest section on either side of the contraction. The discharge through the meter varies directly as the square root of the drop in pressure from the largest section upstream to the throat. For use in pumping stations the meter is furnished with an autographic recorder, which shows, by a diagram, the volume of flow. A diagram of the meter is shown in Fig. 9.

A very decided advantage of the Venturi meter is that the loss due to friction is small. The meter is very accurate, for large discharges, more accurate than any other meter.

For domestic supply the favorite meter in America is one of the positive types, usually the rotary piston or disc meter. The double cylinder reciprocating piston meter is also used frequently. European practice seems to favor the use of inferential meters for this purpose. The explanation is probably found in the different number of persons per service in America and in Europe. In America the number of people using one service is probably about ten on the average. In some cities it is as low as five. In Europe the number is much larger. In Berlin, for instance, the latest figures available state that there are 70 people per service. With this condition the flow would be fairly continuous and a cheap compact meter which will give a reasonably corrcct measurement is therefore used. The average number of people per service is large in nearly all European cities.

For trade supply inferential meters are almost universally used. It should be noted that inferential meters may pass large quantities of water without registering, as, if they become "stuck up" they offer very little resistance to the flow.

For measurements of municipal supply the Venturi meter is used. The Pitometer, a rated pitot tube arranged to give a photographic record of flow, is coming into use for this purpose also.

PRACTICAL METHODS OF CONCRETE CONSTRUCTION*

C. G. CLINE, '09.

This paper is not intended as a discussion of the theory of concrete, either plain or reinforced; it is intended simply to bring out some methods of concrete construction met with by the writer in a somewhat limited experience with this important material of construction.

One of the simplest uses of cement is the making of mortar for brick or stone work. It is often used where mortar made from ordinary lime would not be strong enough; or a small quantity may be mixed with lime mortar to increase its strength. When the masonry is to be exposed to moisture, cement must be used instead of lime, as lime will not set unless thorougly dry, and will gradually dissolve in water.

Cement in the form of concrete is now very commonly used for all kinds of walls, for buildings, retaining walls, dams, etc., and for foundations for buildings and machinery. Wooden forms are built up, the concrete is mixed by hand, or by machine, and placed in them. The concrete takes up the shape of the forms and hardens, so that when they are removed the wall remains.

The forms are almost universally made of lumber. The use of steel, either for the entire forms or for facings, has not been found satisfactory. The steel plates are easily bent and it is too expensive to be continually straightening them out. A common practice is to use 2″ lumber for lagging and 2″x6″ for studs. If 1″ lumber is used, the studs will need to be much closer and the bracing of the forms very carefully attended to. Even then the results may not be satisfactory; the whole wall may get out of alignment, or some of the boards may spring out of place and leave a rough, uneven surface on the wall.

---

* Read before Civil and Architectural Section of Engineering Society, December, 1908.

For rough work, undressed lumber is commonly employed. On one structure, undressed lumber was used for the foundation and inside work where it would not be exposed to view. For finer work, lumber was employed which was dressed on one face and both edges; the edges must be dressed and straightened so that the planks will fit together tightly in the forms and not leave holes for the concrete to run through, making great ridges on the wall. On still more particular work, there was used matched lumber, 2″x8″ or 2″x10″. The tongues and grooves made the form much more solid and easier to keep in position and gave an even face on the finished wall.

When an especially smooth face is desired, it is a good plan to paint the inside of the forms with a coating of soap dissolved in hot water. This allows the forms to come off clean, without damaging either the lumber or the concrete. It is surprising how tightly a piece of wood will stick to the concrete wall, even when it is merely in contact with it; while if it is partly imbedded in the concrete, it is next to impossible to remove it when once the concrete has set. In foundations for machinery, it is necessary to leave a space around each anchor bolt so that it will have some play when the casting is being placed in position. This is usually done by placing a long, narrow box around each bolt before the concrete is put in the forms. These boxes should be tapered and must be removed before the concrete is entirely set or it will be impossible to withdraw them. After the machine is properly lined in, cement grout is poured into the holes, and when it hardens the machine is held firmly in position.

If it is desired to nail any wood-work to a cement surface, a piece of scantling placed against the inside of the form will become imbedded in the concrete when the form is filled and will make a solid nailing strip to which the wood-work can be fastened.

The form for a concrete wall consists of two walls of lumber. The smooth side of the lumber, if it is dressed, is, of course, placed to the inside. The studs, usually 2″x6″, are placed on the outside. The concrete, as generally used, is rather wet and soft, and when placed in the form it exerts considerable pressure in every direction. Concrete is more than twice as heavy as water, and so, although it is not as fluid, it will exert almost as great a pressure as would water. This pressure tends to move the two walls of the form apart and must be provided for in some way.

Where the wall starts from the ground and is only five or six feet high, the two sides may be held in position by braces slanting from the ground. But in very many cases this method cannot be used, and it becomes necessary to tie the two walls together. One very effective method is to use bolts which can be tightened up by nuts, wooden spreaders being used between the walls to keep the form the proper width until the concrete is placed in. In narrow walls the bolts can be driven out after the forms are removed and used again; the holes left in the wall are plastered up. But in many cases the bolts would have to be left in the wall and the ends simply cut off. The rods serve no useful purpose in the wall and their cost is considerable. A plan, which is considerably cheaper and almost as effective is to tie the walls together with strands of wire twisted until a sufficient tension is obtained to resist the pressure of the concrete. As in the last case, spreaders are used to keep the walls properly spaced. They are always removed just before the concrete comes up to them.

To avoid excessive pressure on the forms, and for other reasons, concrete is laid in layers, often not more than two feet. To make a solid wall, it is essential that these separate layers adhere to one another strongly. For this reason, when a fresh layer is being placed, the bottom layer should be perfectly clean and should be wet. The concrete is usually swept as clean as possible, and then washed with water. To make a really good joint, it is a good plan to sprinkle a little neat cement over the bottom. Sometimes the first two or three inches of the fresh layer is mixed with a little less stone in it, to ensure plenty of fine stuff at the joint. When leaving work for the day, it is a good practice to imbed plenty of big, sharp stones in the concrete, leaving half of each stone sticking up to give a good bond for the next layer. In narrow walls, where stones could not be used, short pieces of bars of iron or steel scrap or old pipe will serve the same purpose.

In starting a wall on smooth rocks, especially if the rock be sloping, great care must be taken to make sure that the wall will not slip. The rock surface should be thoroughly cleaned and washed and holes drilled at intervals and fox bolts driven in.

For ordinary work, concrete is usually mixed with a considerable amount of water, so as to make it quite soft. Then, when it is placed in the forms, it will, with the aid of a little tamping, work into all the corners and make a smooth face and a good bond. One defect of this method of mixing is that when the water evaporates it leaves the concrete more porous and diminishes the strength to some extent.

For some work, the concrete is mixed rather dry, almost like moulding sand. If properly tamped, this will be less porous and rather stronger than the other mixture; but it requires a great deal more care in handling it to be sure every corner is filled up and no holes left. If it is not carefully tamped its strength will be greatly impaired. It is not so well adapted for ordinary walls and foundations, but is used where it has to be trowelled, such as for the top coating of floors and sidewalks.

In concrete work it is customary to mix the cement, sand, gravel and stones up to, say, two inches diameter, together in the mixer or on the board. But in most cases it is desired to use stones larger than two inches. These larger stones are taken to the forms by themselves, thoroughly washed and soaked in water, and placed in the form one by one. In a three-foot wall, rocks as big as two feet across may be used if carefully placed; and even in an eight-inch wall, four-inch rocks are all right. In one instance, old bricks were laid in an eight-inch wall with the four-inch side horizontal. Of course, the extensive use of fillers is not permissible on all works; they diminish the strength of the work to some extent and its fire-proof qualities.

In using fillers, care must be taken to keep them back a sufficient distance from the face of the wall. If a flat surface of a rock or brick comes within an inch or two of the face, the thin layer of concrete on it is apt to come off with the forms or be knocked off in some way and leave an ugly hole in the wall, exposing the filler. The same is true, to a lesser extent, of the smaller stones. But these cannot be placed by hand. So it is necessary in every wall to have a man run a spade or other tool up and down against the face of the form in such a way as to work the stones back and to give the fine part of the mixture a chance to make a smooth, even finish.

In most works it is impossible to carry up the whole structure at once. So it becomes necessary to make some provision for joining the different sections together. One method of doing this is put steel rods in the first section, leaving half the length of the rod projecting at the joint. The ends of the rods are usually bent to increase their efficiency. Another method is to nail on the inside of the form several blocks of wood slightly bevelled so that they may be removed readily. This leaves a recess into which the concrete in the other section will run.

In attempting to use concrete in cold weather, the difficulties are greatly multiplied. If concrete is allowed to freeze the setting is arrested, and the strength of the concrete greatly weakened by the destruction of the cement crystals. Another danger in frosty weather is that the grains of sand, the stones, the larger rocks on the bottom of the wall may be coated with ice, so that the cement will be given no chance to adhere to them.

Great care must be taken to see that everything used in the concrete is above the freezing point and will remain so for several hours after being mixed, so that the concrete will have a chance to set properly. The water can be made quite hot by running steam into it. The cement forms only a small proportion of the materials and need not be heated. The stone, gravel and sand are heated by piling them over long flues laid on the ground at a slight inclination. The flues lead the heated gases from fires in the fire-boxes along under the piles of material to a low stack at the upper end. The larger rocks can be conveniently heated by immersing them in hot water, or by keeping them for some time in a large enclosed box with steam turned into it. A good way to warm, and at the same time to clean the concrete at the bottom of the form is to use a steam jet under a low pressure. This will warm the concrete and the forms and thaw any ice which may have been on them and can also be used to blow the dust, saw-dust and chips into little piles where they can be removed. Hot water is not very good for washing the forms in really cold weather, as it will soon cool and freeze, making things much worse than before; the walls should be left as dry as possible until just before the concrete is ready to be put in.

Considerable care is necessary in taking the concrete from the mixer to the forms. If conveyed in steel wheel-barrows or boxes, they should be rinsed out with hot water before being loaded. On one job it was necessary to hoist the concrete with a derrick and then dump it out and shovel it into wheel-barrows. In this case the concrete was dumped into a flat iron box with a fire under it and so kept warm until the wheel-barrows were ready to take it to the forms.

As soon as the concrete has been placed in the form and properly tamped, it should be covered over in some way to keep in the heat. One good method is to have long canvas sacks prepared of a proper size to fit in the walls and fill them with straw. These, when placed over the warm concrete, will keep in the heat for some time.

In one case, on a thin wall on an exposed part of the work, a line of old steam pipe was laid right in the form and left there. The concrete was placed around it and steam was kept running through the pipe for several hours until all danger of freezing was past.

EDITORIAL AND BUSINESS BOARD, APPLIED SCIENCE, '08-'09

A. R. DUFF L. R. WILSON R. J. MARSHALL W. J. BOULTON F. CHESNUT
H. W. PRICE, B.A.SC. M. C. BOSWELL, M.A., PH.D. P. GILLESPIE, B.A.SC. W. TREADGOLD, B.A.
K. A. MACKENZIE, B.A.SC.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 APRIL, 1909 New Series Vol. 2, No. 6

CEMENT*

E. ASHTON HASSAN.

Gentlemen:—It is with a certain amount of diffidence that I stand here this evening, for, appearing before a number of men of your standing and ability carries with it an honor that could not be eclipsed and for the privilege of which I desire to tender my sincerest gratitude. Knowing something of the value of your time, I fear almost to present my material before you, fearing I may fail to some extent and thereby waste your valuable time, and were it not with hopes that my paper would be beneficial to most of you I never would have accepted the invitation.

History chronicles vaguely the events of a period known as the Stone Age, when men wrought with the crudest tools and implements and eked out the merest existence. But man's necessity made him progressive and his cunning taught him to devise instruments superior, of bronze, with which to serve his purpose, only to find them on further advancement inferior to the improved work of his son in the Iron Age. Each plays its part in the economy of Nature, then yields place to its betters and the Stone Age, Bronze Age and Iron Age seem to be yielding the palm to the Imperial Age of Portland cement. Apparently no product in the world has wider application than Portland cement, a man telling me a little while ago that his wife had patched up her leaky wash-tub with it some six months ago and up to date it was still in good condition.

Men are beginning to realize more and more its worth, especially with regard to its fireproof qualities, wherein brick, stone, terra cotta, iron and steel all suffer in comparison with it. The great ultimate strength that can be gotten in conjunction with steel in the form of the now widely known and yet unknown form of reinforced concrete. It is, as we heard a few weeks ago in a lecture—I refer to the "Artistic Bridge Building Design"—the ideal building material in bridge construction, whether for strength, form, beauty or durability. Probably there is no material on earth better adapted for street paving or sidewalks, etc., and the many objections raised are usually prompted by the inferior workmanship and lack of knowledge concerning this very important branch of construction.

---

*An address delivered before Chemical Section of Engineering Society, January, 1909, and awarded 1st prize for Student's Paper.

In house construction, although time has not been given as yet to ornamentation, there is no limiting the possibility of cement with regard to the "house beautiful." The exhibition given during the next week will in all probability be a revelation to you in this direction. It has been treated to very good effect, as might be seen in the buildings of St. James Church, Brooklyn, N.Y., club house of Detroit Boat Club, Nassau County Court, Mineola, Long Island, and very many others, a few illustrations of which are here for your approval.

While once the structural steel buildings were thought absolutely fireproof and safe, it is now almost universally conceded that it must be supplanted by reinforced concrete. There seems little doubt but that Portland cement has made work of such magnitude as the Assuan Dam, the marvellous docks of Buenos Ayres and the Panama Canal, engineering feats capable of being successfully handled.

It might be well for us to note with what rapidity the manufacture of this product in the United States and Canada has grown. In the United States, in 1892—547,440 barrels: value $1,153,600; 16 plants; in 1904—26,505,881 barrels; value $23,355,119; 75 plants; in 1908 it had reached 49 millions. I take my last figures from the paper recently read before the Canadian Engineering Society by Dean Galbraith.

While not being able to quote the exact figures for Canada's production, from the business in which we have been engaged during the last few years, it has at least been increased about one-and-a-quarter million barrels and with the two new plants here in Ontario and two near Montreal, you will be able to judge for yourselves its growth.

Year	Canadian Barrels.	Imported Barrels.	
1904	910,358	784,630	1,694,988
1905	1,346,548	917,558	2,264,106
1906	2,119,764	694,503	2,814,267
1907	2,436,093	672,630	3,108,720
1908	2,665,289	457,408	3,122,697

Detailed statistics for past two years are as below:

	1907	1908
Portland cement sold	2,436,093	2,665,289
Stock on hand Jan. 1st	299,015	383,349
Portland cement manufactured	2,491,513	3,495,961
Stock on hand Dec. 31st	354,435	1,214,011
Value of cement sold	$3,777,328	$3,709,063
Wages paid	956,080	1,274,638
Men employed	1,786	3,029

There are about twenty-three plants in Canada, of which twelve use marl and clay and ten use limestone and one slag.

Nor can we say that this remarkable progress is to end here, for many have been the calls for the erection of plants, and one firm capable of nearly 3,000 barrels per day capacity, have if their machines run at their full capacity day and night until the end of the year, sufficient orders now to take all they make, and are thus seriously considering the duplication of their plant. If you will pardon an interpolation at this point, may I say that it is an erroneous conception of the manufacture of cement that has led people to believe that plants can be erected and worked profitably on a small scale and at small cost, and to disprove this theory will be in some respects the aim of this paper.

It would be advisable that we at this juncture acquaint ourselves with the material under discussion and find out what Portland cement really is.

There appeared in the Crawford (Nebraska) Tribune in 1906, an article in which the editor, evidently mutilating the words of Prof. Barbour of Nebraska, said: "Nebraska has almost inexhaustible beds of impure limestone, which is the material used in the manufacture of cement, but at the present prices of fuel this wealth of building material cannot be manufactured at great profit. The process of manufacture is very simple. Impure limestone mixed with sand is ground up and water added to make a thick paste. This flows through an iron pipe heated to a white heat so that the paste becomes dry and finally emerges from the end of the pipe as clinkers, which fall into a stone crusher, and pass between rollers, the dust falling into sacks ready for market." Now, gentlemen, this may be an exaggerated case apparently prepared for the mind of a western cowboy, nevertheless something of the above state of affairs exists quite largely in the large and busy cities of this country with regard to Portland cement and its manufacture, a school man asking me a few days ago if plaster of paris was put in to make cement harden.

Cement may be said to be a material which when pulverized and mixed with water into a paste, acquires the property of setting and hardening under water.

In engineering construction three kinds are known: Pozzuolana cement, natural cement, and Portland cement. Pozzuolana is obtained by grinding together an intimate mixture of slaked lime and blast furnace slag or volcanic scoria. The cement is not burned, the hydraulic ingredients being present only as a mechanical mixture, hence it never gained general acceptance. This must not be confused with slag Portland, which is regular Portland, the slag furnishing the silicious ingredients, taking the place of shale or clay in the mix.

Natural cement is the product resulting from the burning and subsequent pulverization of argillaceous limestone or other suitable rock in its natural state, the heat of burning being sufficient to cause vitrification. If, gentlemen, there were more time at our disposal, I might be inclined to give this a further consideration, but it must of necessity, owing to the title of my paper, be relegated to the background with a hope of further study on some future occasion.

Portland Cement.—In what follows in this paper the discussion will be now limited to Portland cement, so that whenever the unqualified term "cement" is employed, Portland cement alone is to be understood.*

Le Chatalier in 1897 published as his thesis for the degree of Doctor of Science a dissertation upon "The Experimental Study of the Constitution of Hydraulic Mortars," in which he propounded a theory that Portland cement was composed of two essential compounds, tricalcium silicate $3CaOSiO_2$ and tricalcium aluminate $3CaOAl_2O_3$. (Journal Soc. Chem. Ind. XI, 1035.) Spencer B. Newberry ten years later confirmed the views of Le Chatelier concerning the tricalcium silicate, but held to the theory that the alumina was present as dicalcium aluminate $2CaO.Al_2O_3$. In 1906, Day and Shephard (Am. Chem. Soc., XXVIII, 1089, also Chem. Eng. IV, 273) read a paper before the American Chemical Society in which they stated that no such compounds as tricalcium silicate exists and that the compound so called by others is a mixture of lime and orthosilicate (dicalcium silicate). We thus find within twenty years three radically different theories and we would expect that these revolutions of theory would have some influence upon the practical manufacture of Portland cement and the ultimate composition of the commercial product.

R. K. Meade analyzed a sample of cement in 1896 and one in 1906 and says: "I doubt if both samples had been drawn at either time, from cement made a few days apart, they could not have agreed more closely."

It must not be supposed, though, from what I have just quoted that cement is not better to-day than ten years ago; that would be fallacious, for in fact it is on an average very much better, but this progress has been due to the improved mechanical appliances rather than to any new ideas of how to make Portland cement, especially with regard to the fine grinding of the raw materials.

The generally accepted theory concerning Portland cement, which by the way is taught in the School of Practical Science, is the one propounded by Newberry, and which leads us as follows: Assuming that the trisilicate and dialuminate are the most basic compounds which can exist in good cements, we have the following formula: $X (3CaOSiO_2) + Y (2CaOAl_2O_3)$ in which X and Y are variable quantities having different values according to the relative proportions of silica and alumina present in the clay employed.

Ref.—Annoles des Mlnes, 1887, p. 345, also translation by J. L. Mack; McGraw Publishing Company, New York.

The formula $3CaOSiO_2$ corresponds to 2.8 parts of lime by weight to 1 part of silica.

The formula $2CaOAl_2O_3$ corresponds to 1.1 part of lime by weight to 1 part of alumina, and substituting weights for equivalents we have what is known as Newberry's Hydraulic Index, representing the maximum of lime which should be present in a correctly balanced cement. % lime = % silica × 2.8 + % alumina × 1.1. If we take lime and silica in the proportion of 2.8 and burn them thoroughly, we get hydraulic properties slow setting but ultimately developing great strength. We would draw from this the conclusion that the tricalcium silicate contributes to the cement its ultimate strength and hardness.

On the other hand, treat lime and the aluminate in their proportions above named, burn them thoroughly and on pulverization we get material which exhibits quick-setting properties and we thus judge that the dicalcium aluminate contributes to a cement its quick-setting properties, and that a cement high in the aluminate will be a quick-setting cement. Now taking the formula and using it to calculate the proportion of lime to be used for a clay of a known composition, we proceed: × % of silica by 2.8, the Al_2O_3 by 1.1, add the products; the sum will be the number of parts of lime required for 100 parts of clay.

As 2.8 parts of lime correspond to 5.0 parts of carbonate of lime and 1.1 parts of lime coresond to 2.0 parts of carbonate of lime, the calculation for factory work takes the following simple form: 5 times the % of silica + twice the % of alumina = the number of parts of carbonate of lime required for 100 parts of clay. A practical example: Suppose a clay on analysis had this composition: Silica 65.4, alumina 16.5, iron oxide 6.1, lime 2.2; magnesia 1.9; moisture, etc., 7.9; total 100. Let us calculate the amount of lime or carbonate of lime which must be added to this clay to produce a lime correct cement mixture.

$$
\begin{array}{lr}
\%\ \text{silica} = 65.4 \times 2.8 = & 183.12 \\
\%\ \text{alumina} = 16.5 \times 1.1 = & 18.15 \\
\hline
 & 201.27 \\
\text{Less lime in clay} & 2.20 \\
\hline
 & 199.07
\end{array}
$$

199.07 parts lime for 100 of clay.

As 56 parts of lime correspond to 100 of carbonate of lime we have $\frac{199.07 \times 100}{56} = 355.5$ parts of carbonate of lime for 100 parts of clay, the correct mixture now reading:

Clay, 100 parts.
Pure $CaCO_3$ 355.5.

The % of carbonate of lime in this mixture would be 78%. On burning this a high grade cement would result, providing the raw materials were very finely ground and perfectly mixed and fully calcined.

You will understand, of course, that this represents, as was previously stated, the maximum of lime that may be used in safety.

Seeing that of late date magnesia and iron are allowed for, a correction by the way which seems advisable, I will endeavor to give the steps for proportioning a cement mixture accordingly.

Operation 1.— × % of silica in clayey material by 2.8, the % of alumina by 1.1 and the % of iron oxide by 0.7; add the products; subtract from the sum thus obtained % of lime oxide in the clayey material plus 1.4 times the % of magnesia. Call the result *n*.

Operation 2.—Multiply the % of silica in calcareous material by 2.8, the % of alumina by 1.1 and the % of iron oxide by 0.7; add the products and subtract the sum from the % of lime oxide plus 1.4 times the % of magnesia in the calcanous material. Call the result *m*.

Operation 3.—Divide *n* by *m*. The quotient will be the number of parts of calcareous material required for 1 part of clayey material. Example:

Assuming the following compositions of

	Clay	Limestone
Silica SiO_2	62.2	2.4
Alumina Al_2O_3	16.1	2.0
Iron oxide Fe_2O_3	4.2	0.3
Lime (CaO)	1.6	50.2
Magnesia (MgO)	1.2	1.5
Sulphur trioxide (SO_3)	1.7	0.6
Alkalies ($K_2O.Na_2O$)	0.8	0.4
Water, CO_2 etc.	12.2	42.6

Operation 1. Clay—

Silica $\times 2.8 = 62.2 \times 2.8 = 174.16$
Alumina $\times 1.1 = 16.1 \times 1.1 = 17.71$
Iron oxide $\times 0.7 = 4.2 \times 0.7 = 2.94$

194.81

Lime $\times 1.0 = 1.6 \times 1.0 = 1.6$
Magnesia $\times 1.4 = 1.2 \times 1.4 = 1.68$

3.28

$\therefore\ 194.81 - 3.28 = 191.53 = n.$

Operation 2. Limestone—

Silica $\times 2.8 = 2.4 \times 2.8 = 6.72$
Alumina $\times 1.1 = 2.0 \times 1.1 = 2.20$
Iron oxide $\times 0.7 = .3 \times 0.7 = 0.21$

9.13

Lime	$\times 1.0 = 50.2 \times 1.0 =$	50.2
Magnesia	$\times 1.4 = 1.5 \times 1.4 =$	2.10
		52.30

$\therefore\ 52.30 - 9.13 = 43.17 = m.$

Operation 3.—

$$\frac{n}{m} = \frac{191.53}{43.17} = 4.44 \text{ parts of limestone}$$

to be used for each part of clay by weight.

Again let me remind you that the value given by the above formula represents the highest amount of lime theoretically possible, and under best conditions procurable at the present stage of the industry one needs to reduce this about 10% to get satisfactory results and we may therefore safely state according to above that

4.44 = parts limestone to one of clay.
0.44 = 10% reduction for safety.

4.00 = parts of limestone to 1 of clay to be actually used.

I would like to have given examples to you of the physical tests, but as these are taught in the university you will no doubt at a later date come into intimate contact with them.

Chemical analysis of the finished product is rarely resorted to as hardly any adulteration takes place owing to the fact possibly that it is just as easy to make good cement as a poor one, providing parties have sufficient knowledge of the essentials of its production.

I feel that I have hardly done justice to the most important phase of cement, namely the chemical, but I have attempted in a brief way to bring before your notice its composition and it will, I would presume, stimulate a greater interest in the discussion concerning its manufacture. Speaking personally, I do not feel in any way competent to discuss at great length the subject of which I am here to learn.

We are now fully prepared to deal with the raw materials, and one word here of warning; probably some of my hearers will be called sooner or later to pass judgment upon deposits of marl, lime, clays or shales respecting the advisability of putting in a cement plant. A great responsibility therefore rests upon such a one, and a few important things to bear in mind are:

1. Chemical composition of the material.
2. Physical character of the material.
3. Amount of material available.
4. Location of the deposit with respect to transportation routes.
5. Location of the deposit with respect to fuel supplies.
6. Location of the deposit with respect to markets.

Just a word with regard to No. 3, amount available. A plant running on dry raw materials such as a mixture of lime per kiln; of this about 15,000 will be limestone, 5,000 shale. and shale will use about 20,000 tons of raw material per year Assuming limestone weighs about 4,400 lbs. per yard and the shale 3,300 lbs. per yard, let us remember it would be folly to erect a plant on property with less than twenty years' supply. For each kiln of the proposed plant, then, there must be in sight at least 3,800,000 cubic feet of limestone and 1,600,000 cubic feet of shale.

With regard to fuel supplies, let us remember each kiln with the requisite crushing machinery uses up from 6,000 to 9,000 tons of coal per year.

There are two modes of manufacture of cement, the dry and the wet process, the difference in short being that in the dry process the material enters the kiln dry, while in the wet it is pumped into the rotary as a slurry. Many men have thought that using wet marl constituted the wet process, but such is not the case, for if the mix be dried previous to its entering the rotary it is called the dry process.

Taking the case of a limestone and clay. The limestone is quarried usually by blasting with dynamite and the opening should be so located as to give as little stripping as possible, for stripping is merely dead work, adding greatly to the expense of the product. The prevailing practice is to open up the quarry on a low hillside, so as to give a long working face and blast down in benches. The rock is sometimes loaded in cars hauled by locomotive or horses to the mill, but the better way is to have a cableway installed of the type to be shown in one of the slides, which has a great advantage and is called a twin cableway, and the two towers farthest from the mill are on rails so that they may be moved in any direction and thus facilitate the handling of the rock, also use of two buckets.

In a plant recently erected where the limestone is on the mountain side, the shelf has been cut sufficiently high to allow sufficient grade for cars to run down to the crusher by gravity and situated at the crusher dump is a short car haul lifting the cars onto a trestle bridge where they receive sufficient impetus to go back to the quarry without further aid. This has proved possibly the cheapest method of handling, but natural advantages of this description are not always obtainable. The material is dumped into a Gates crusher or one of similar type, the modern method employed by the largest plants in Canada being to have a No. 7 Gates crusher, the material falling from this into a perforated revolving cylinder, the pieces not going through the perforations falling down into a No. 4 crusher, the aim of the manufacturer being to get the rock into pieces from 1½ to 3 inches in size to make them easier to dry, the material having a like area submitted to the heat, all then being uniform with regard to moisture.

Provision is made for the storage of hundreds of tons of the rock so that in case of bad weather when men cannot work in the quarry, the mill will not suffer and sufficient is usually stored for seven days' run.

The first crusher will take rocks up to 18"x45", and is capable of breaking about 120 tons per hour to 2½", driving pulley running about 350 R.P.M. with a 110-h.p. motor and is worth about $6,000; while the No. 4 will take the pieces from the cylinder and handle them with a 50-h.p. motor very easily, the price of this being about $3,000. The two motors will cost about $2,000.

The rock is taken from the storage by the same conveyor used for filling the storage, the best type being what is known as the Peck overlapping bucket conveyor, which is essentially an endless chain of buckets, each pivoted to a bar so that they might swing on their central axis and maintain an horizontal position when running up the towers. This conveyor runs about 150' per minute and is worth, installed, about $15 per foot, and is without doubt the most expensive style of conveyor in modern use, but its perfect running and the fact that it never gives occasion for stoppages fully warrant the initial expenditure.

I will endeavor to explain the different modes of conveying and their relative values by means of the slides later.

The material is carried by this to hoppers placed above a dryer, which is, as you will see by drawing exhibited herewith, an iron cylinder about 5' in diameter and 50' to 80' in length, set at an inclination of about ¾" per foot, turning at three revolutions per minute. Inside are four plates (perforated) projecting out from the sides to within eight inches of the imaginary centre. The material is fed through a water-jacketed cast-iron pipe and fire applied by means of a furnace whose gases play directly into the dryer. From this the dry rock is elevated to the Ball mills for grinding. There are several types of pulverizing mills which are used at this stage, one well known and at one time largely used being the Griffin mill, of which I will show a picture later and which I will then describe. There is also the Kent mill, Huntingdon, Lehigh pulverizer and Kominuter. Ball mills are made by a number of manufacturers but the types mostly found in cement plants are the Schmidt, Gates, and Krupp; there is very little difference in their mechanism. I have here for your notice drawings of a Ball mill. The machine has a through shaft with journals running in bearings at both ends. The machine consists of a drum with two strong end plates between which curved drum plates are fixed. These plates do not form a cylinder, but one end of each is set a few inches nearer the centre, thus forming steps, the balls and material falling over these steps when the drum revolves and thus the material is pounded. The drum is surrounded externally by a fine cylindrical phosphor bronze or steel wire gauze fit in narrow sections so that they may be taken out and replaced with finer gauze according to degree of fineness required; the ones often used are 20-mesh $125 phosphor bronze wire open

.05 — 016 = .034″. Each section requires piece of screen 27″x51″ and twelve to each mill.

The Ball mill contains iron balls as follows: 87 5″ balls, 18 pds. each; 128 4″ balls, 10 pds. each; 300 3″ balls, 5 pds. each; net 4,366 lbs.

The drum revolves at 21 R.P.M., requires a 75-h.p. motor and can grind to a residue of 76.2% on a 100 sieve 21 barrels per hour. A Griffin mill will reduce about 5 bbls. per hour to 95% pass a 100 mesh.

From the Ball mills the rock is transferred by means of a screw or spiral conveyor to large steel wood-lined bins. Experience has led us to always keep steel from contact with the rock or cement as the steel sweats and moisture is thus imparted to the material, while the main idea is to keep it dry. It is during its storage in this bin that the rock samples are taken and analyzed, the bin being partitioned off into six divisions. After analysis it is ready for the scales. While this process has been going on a similar process with the exception of the use of a Blake crusher for reducing to size, has been going on with the clay, and we find bins of like manner but much smaller now filled with coarse ground clay which is awaiting the verdict of the chemist. After the report has been received from the chemist the materials as per his instructions with regard to weight, are now weighed.

From the weighing hoppers the two materials are dropped simultaneously into a screw conveyor which to some extent mixes the two, which is now called the "mix." The mix is elevated and conveyed to hoppers above the tube mills and is automatically fed into them, and by constant turning in the tube becomes perfectly mixed as well as perfectly pulverized.

The tube mill is a cylinder usually about 5′x22′. It is filled to 4″ above centre line with flint pebbles. The mill makes 27 R.P.M., contains about 11 tons of pebbles and requires about 64-h.p. motor. They will grind that 95% pass 100 mesh and residue a 20 mesh. Their capacity is about 13 bbls. per hour, but here are records in which a mill ground 5,854 yards in 963 hours, or 6.07 yards per hour; on another occasion 8,493 yards ground in 1,357 hours, or 6.2 yards per hour. A mill is worth about $2,500 and thus with Ball mills at $4,500 a battery will figure installed at about $10,000.
and is taken to an elevator and lifted to a large bin standing

The mix leaves the tube mills, falls into a screw conveyor above the rear end of the kilns.

We have now arrived at the most important branch of Portland cement production. Given the best chemists and an absolutely perfect mix for combination, carelessness at this stage would prove disastrous.

The rotary kiln as at first used in cement manufacture was only 40′ long and at Sandusky, Ohio, some sixteen years ago two were joined together and new gearing placed in under the superintendence of R. D. Hassan, in conjunction with our foremost cement chemist, Mr. S. B. Newberry. This so revolutionized the manufacture that engineers in the cement industry after visiting Sandusky immediately adopted it and it has been little changed since.

I have here drawings of the friction wheels and driving gear as they are used to-day.

The 80′ rotary, then, is practically the most universal, although at present time we are using 90′ and will in the next factory put in 100′ kilns. Allow me to here state that where the wet process is used the longer the kiln the better, and 150′ is about the most economical for such purposes. They range from 6′ to 9′ in internal diameter. Lined with very resistant fire brick about half-way down the kiln from 6″ to 10″ in depth to withstand both the high temperature to which its inner surface is subjected and also the destructive action of the molten clinker. Our present kilns are not always of equal diameter throughout, some being smaller at the stack end, accomplished by means of a reducing section just beyond the middle in the shape of a frustum or cone.

The theory being based on the gases cooling as they near the upper end should be confined to a smaller area to keep their efficiency.

With a 90′ rotary pushing it very hard it is possible to get 240 lbs. per day.

For the firing of the kiln and burning of the cement, oil, gas and coal have been used. Natural gas is used in some plants both in the States and here in Ontario, and the chief objection is that you cannot force a kiln with gas like you can with coal. Oil is generally accepted to be the best and was certainly at one time the cheapest material for burning cement, 1 gallon of oil being equivalent to 12 lbs. of coal, or 1 lb. of oil = 2 lbs. of coal.

The question of fuel consumption is the one which agitates the mind of the cement manufacturer and it is in this feature possibly more than any other which offers best prospect of improvement in the matter of economy. Owing to diversity of conditions at different factories a calculation can only be approximate. The amount of coal used in burning a barrel of cement is about 110.120 lbs. for dry material and 150 to 160 for wet material 50% water.

The actual burning of cement consumes a definite amount of heat which is absorbed in evaporating, the water contained in the material heating up the dry mixture, decomposing the carbonate and sulphate of lime present, heating the gaseous products to the stack temperature and finally heating the calcined material to the point of sintering. As the specific heats of decomposition of all these substances are known it is possible to calculate approximately the number of heat units and amount of fuel which should theoretically be required to produce a barrel of cement under various conditions.

Let us assume the use of a coal which has a theoretical value of 13,400 heat units and for its combustion requires 10.2 lbs. of air per pd. of coal. Assuming that the temperature of the kiln building is 70° F. and products of combustion escape as they often do at 1500°, we will work out that

2.75 lbs. CO_2 sp. ht. .22 at 1500 =	871
.464 lbs. water sp. ht. .48	321
8.065 lbs. N. sp. ht. 24	2,794
	3,986

If 50% more air be added than theoretically required this will absorb 1,763 h.u. The available heat of 1 lb. of this coal will therefore be 13,400.

Products of combustion consume 3986, then heat units available with theoretical air will be 9414 and 50% more air consumes 1763; the heat units available with 1½ theoretical air will be 7,651.

Let us now assume the mix is $CaCO_3$ 75%, SiO_2 15, alumina and iron oxide 5, mg. and alkalies 2.0 combined, water 2.0, SO_3 1.0. 600 lbs. of this mix will give 384 lbs. of cement, the balance representing CO_2 water and SO_3 passing off in gaseous form at stack temperature.

The heat units will therefore be the mix introduced at the upper end in the form of dry powder and the clinker discharged white hot at a temperature of about 2,500° *F.* and the gaseous products leaving the kiln at 1,500° *F.*

450 lbs. of carbonate of lime decomposed at 765 . .	344,250	54.7
12 lbs. of water evaporated and heated 60° to 1,500°	20,832	3.3
6 lbs. of sulphuric anhydride liberated at 1,890 . .	11,340	1.8
600 lbs. of mix, heat 60° to 1,000° sp. ht. .2 . .	112,800	18.0
384 lbs. of clinker heated 1,000° to 2,500° sp. ht. .2	115,200	18.3
204 lbs. of carbon dioxide and sulphur dioxide heated 60° to 1,500° at .24 sp. ht.	24,480	3.9
	628,902	100

∴ coal required per barrel of cement

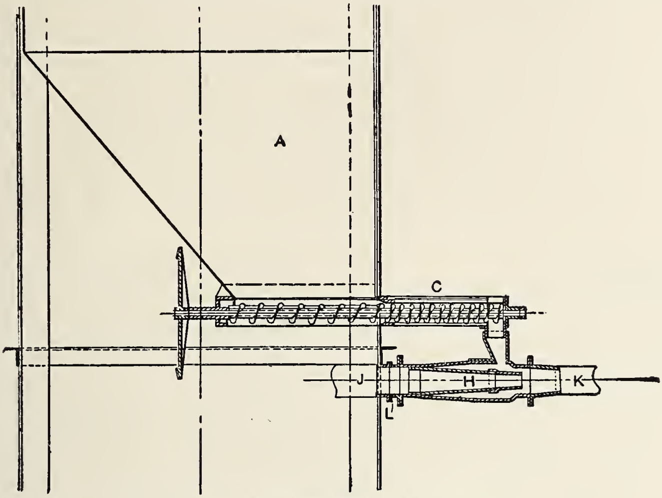
With theoretical air supply 628,902 ÷ 9,414 = 66.9 lbs.

With 1½ times theoret. air supply 628,902 ÷ 7,651 = 82.2 lbs

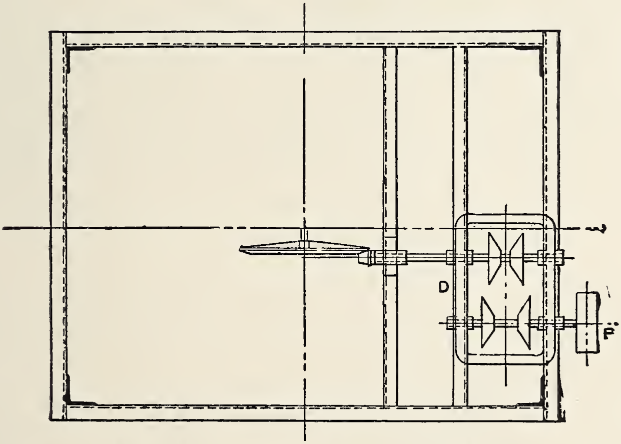
Actually used by us in manufacture, 120 lbs.; difference about 40 lbs.

The above computations are only approximate, but you will readily see that the clinker discharged at 2,500° *F.* will if cooled to 60° give up about 185,000 heat units or enough to heat the theoretical air supply from 60° to 1,143 or 1½ times the theoretical air to 932°. With this in mind the clinker is allowed to drop into a pit from whence the gases and hot air are conducted by means of ducts to the fan for air supply and also to the coal grinding department for use of drying the coal, the hot air being allowed to escape into a rotary drying kiln in which the coal is being passed through.

There is, of course, the gas of the stack yet to deal with, and this could be utilized in much the same way by leading it back over the kiln and using it for air supply, but the foremost cement expert is anxious to keep abreast with the times and is sacrificing at the present time these gases, engaging himself in the design and perfecting of a mode of burning cement by electricity, in which I naturally wish him every success.



DETAIL ELEVATION OF FEEDING MECHANISM



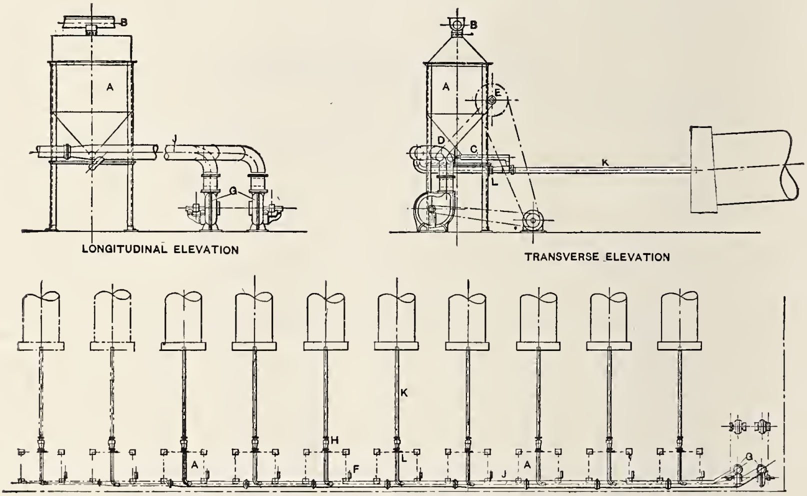
DETAIL PLAN OF VARIABLE SPEED MECHANISM

Coal-burning Arrangement, International Cement Co.

The method of feeding the coal into the kiln I will explain by means of a slide later.

Although some seven or eight years ago the clinker on leaving the kiln was run into towers or cylinders for cooling, the modern method is to transfer it to a storage and let it cool gradually itself, capacity being made for about 100,000 barrels. These bins are filled by means of a continuous conveyor which runs in a tunnel below, then up a tower and covers the entire distance of the rotaries, thereby can be made to dump the clinkers into any part of the storage, so that while one end is being filled with hot clinkers, the cold is taken from the opposite end to the Ball mills for grinding.

After the preliminary grinding by the Ball mills, the material is conveyed to scales, where the right proportion of calcium sulphate or gypsum is added to retard the setting. Just a word here with regard to the addition of gypsum. The high limed clinker which is produced in the rotary process is naturally very quick setting and in order to retard this somewhat, sulphate of lime in the form of gypsum is now universally employed. If added in quantities from 2 to 3 % it retards the set of the cement proportionately, and, strange to say, increases slightly the tensile strength, but in greater quantities its retarding influence becomes less and finally negative. Considerable discussion has taken place as to in which form the calcium sulphate should be added. Crude gypsum is natural hydrous sulphate of lime, formulae $CaSO_4 + 2H_2O$. Plaster of Paris is obtained by heating gypsum at 350 to 400° *F.*, the result being that three-fourths of the H_2O is driven off and we have $2CaSO_4 + H_2O$. If this be calcined at temperature above 400 we get the anhydrous plaster or simply $CaSO_4$. A misleading statement has been made, which is in brief that plaster of paris because of its greater


LONGITUDINAL ELEVATION

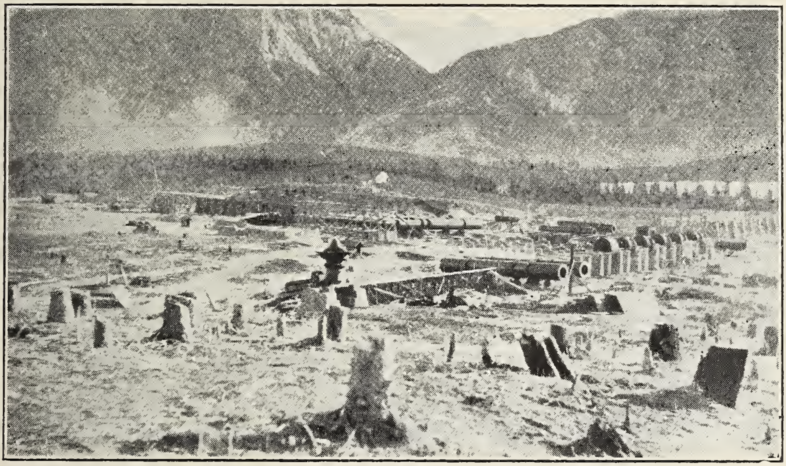
TRANSVERSE ELEVATION

Coal-burning Arrangement, International Cement Co.

chemical activity will be more effective than gypsum, weight for weight. The fallacy involved is revealed when it is considered that the calcium sulphate added to the cement has absolutely no effect until the mixture is gauged with water; and this addition of water will naturally reconvert the plaster of paris immediately into the hydrous lime sulphate, gypsum. Any argument based on relative chemical activity, so called, is therefore fallacious and the sulphate is usually added as gypsum, corresponding tc formula $CaSO_4 + 2H_2O$.

The mixture going through the tube mills becomes intimately mixed and is ground to finished product and then conveyed to the warehouse, where provision is made for about 100,000 lbs.

The bins are usually of plank construction, starting with layers of 2x10 for about four feet, then 2x8, then 2x6, and 2x4 to finish. The material is thus kept from moisture. For preparing for shipment it is conveyed by means of a spiral or belt conveyor in a tunnel to packing room, where it is elevated to hoppers under which are placed scales working automatically, and although their capacity is to bag four per minute, I have run them at six per minute for a considerable period.



Exshaw Cement Plant under construction, showing machines on foundations

In this country a bag contains 87½ lbs., while in the United States they are shipped at 95, four bags to a barrel making a Canadian barrel 350 lbs., and the American 380 lbs.

We have made cement at as low as 55¾ cents per barrel, but if you make them for 90 cents it is considered good work.

A modern six-rotary plant will cost about $800,000, and with a reserve amount of $25,000 per kiln to allow for time, etc., to put the cement on the market, you will readily understand that a million dollars is about the necessary capitalization for a plant to be built and operated successfully. Although we have only built two plants in this country they are the largest and acknowledged to be the best equipped and most modern in the country. One of them last year closed the financial year showing a payment of 18% dividend with $68,000 put to a sinking fund, bringing that up to $250,000.

Never having one bag of cement returned is the record, due I believe to this fact, that the materials during the different stages act so treacherously that it can be said upon the chemist literally hangs the responsibility. I am about to show a diagram showing with what completeness the materials are tested. You will notice sixteen separate tests are made and these through improved storage capacity are made each hour. The samples are being constantly collected. I will show the method.

The two raw materials are correctly analyzed and accurately proportioned before they enter the mill, then a distinct bin analysis is made before mixing.

It is an utter impossibility to produce a uniform Portland cement without a definite mixture of the ingredients or raw materials, hence the great importance of a perfect chemical and mechanical arrangement to accomplish this purpose.

By reason of the prominent place Portland cement now holds in the building arts, more attention is being given to quality by the architect, engineer and builder than ever before in the history of the industry, and it may reasonably be predicted that in the near future the government will inspect and grade cements as they now do other commercial commodities.

Note.—During the lecture numerous slides were thrown on the canvas and raw materials in various stages of manufacture were handed around for inspection.—Ed.

NOTES ON THE CONCENTRATION OF SLIMES

F. C. DYER.

If we shake some crushed rock with water and allow it to subside, we notice a coarse part settles almost immediately—that we call "sands"—and another portion that settles but slowly, and is termed "'slimes."

The terms "sands" and "slimes" are two convenient but loosely applied words. Some writers say "slimes" when fairly coarse sand is included, others restrict the word "slimes" to that finest portion of all, that settles with extreme slowness.

Canvas is peculiarly adapted to catch fine slimes. Mechanical difficulties in making it travel over rollers in belt machines have hindered its use to some extent. Vanners are on the market with canvas belts. Either as a stationary intermittent table or as *slowly* travelling continuous belts it is able to catch smaller particles than any other table..

An attempt was made to observe the movements of particles on a canvas table, with a low power microscope.

It was noticed that the rough hairy surface caused the bottom layer of water to move with unusual slowness favoring the settling of fine particles.

2. The small ridges formed by the crossing of the warp and woof act as riffles, collecting the concentrates, but owing to the slowness of the water at the bottom the cleaning was imperfect.

3. The loose fibres entangle mechanically fine particles that would otherwise float off. Both ore and gangue particles are caught, hence the concentrates from a canvas table are rather lower grade than from other tables. Against this may be set the facts that canvas tables are cheap and catch what would be otherwise lost.

Measurements were made of the size of the smallest particles a canvas table would catch. The same ore was used as in other tests. The coarser slimes were taken out with a slime table. The canvas table had just slope enough to carry off the visible white quartz tailings.

The concentrates were sluiced into a pan, allowed to settle three minutes, and the water with the fine particles in suspension poured off. These particles were given time to settle and measured with a micrometer microscope.

The average diameter was .19 mm or about .0075 inches. With concentrates of greater specific gravity, finer particles still would probably be caught.

The Wilfley slimer, though a canvas table, is painted The hairs are "layed" and the "riffles" partially filled up, therefore probably it cannot catch such fine particles as fresh canvas surfaces.

The rubber belts of Vanners are sometimes finely corrugated or riffled to catch more concentrates.

If the waters in the launders and on the tables is carefully examined it will almost always be found to have particles of concentrates floating on its surface.

If by any chance the concentrates become exposed to the air, as soon as the water again touches them a stream of concentrate particles will float out on the water.

This paradoxical floating of high specific gravity particles on water of low specific gravity is the misnamed Greasy Flotation.

Though small at any particular place, this loss multiplied by the long time it operates may amount to a serious quantity in the operation of a large mill.

Sometimes an inclined blade dipping below the surface of the water is placed across launders to force floating particles below the surface. [1]

The term "floating" here always refers to particles swimming *on* the surface while "suspended" refers to particles swimming *below* the surface.

A more serious and difficult loss to prevent occurs in the suspended particles.

Since the volume of a sphere diminishes as the cube of the radius and the surface only as the square, a point must be approached when the resistance to a particle settling, which depends on the size of the particle, must approximately equal the weight which depends on volume. The closer this approximation, the more slowly the particles fall.

The reasons for slow settling of fine slimes are referred to later.

Since a sphere has a maximum volume for a given surface suspended particles of different shape may be comparatively large and have a slower settling rate than spheres.

To illustrate the loss that occurs in the various sizes of particles, an ore of chalcopyrite and quartz was sent over the tables. The ore was crushed under stamps, the coarse sands removed by a classifier and sent to a Wilfley table. The fines were sent to the slime table. Samples of the feed and tails were taken at intervals. They were dried screen sized and weighed. The assaying was done by the Guess-Haultain electrolytic method.

In the drying the finest particles tend to flocculate and even to form hard lumps, and to stick to the larger grains. Gentle rubbing was employed to disintegrate the floccules, but the weights are only approximate, the finest size through 200 mesh probably being most underweight. If great accuracy were required elutriation methods would be necessary. The assay value of the finest sort will be correct, that of the others slightly high.

---

[1] Callow Mining, Vol. III, p. 94.

The following table shows the weights and value of the feed to a slime table:

FEED.

Mesh of Screen		Per Cent. of Weight	Assay Value Per Cent. of Copper	Per Cent. of Total Copper
On	Through			
100	—	20.49	1.88	10.8
120	100	8.05	2.02	4.6
150	120	3.55	1.71	1.7
200	150	12.92	2.64	9.3
—	200	53.92	4.85	73.3
—	Loss	1.07	—	—

The loss is almost entirely of the finest size. Note, over 50 per cent. passes through 200 mesh and carries over 70% of the total values.

Similarly the tails were screen sized and assayed. Small differences will be noticed in the percentage of sizes of feed and tails, due to the difficulty of making an exact separation. The difference is not enough to affect the conclusions drawn.

Again, note the high percentage of finest sort with high assay value, and that this same size carries over 90% of the total loss.

The following table gives the weights and values of the tails:

SLIME TABLE TAILS.

Mesh of Screen		Per Cent. of Total Weight	Assay Value Per Cent. of Copper	Per Cent. of Total Copper
On	Through			
100	—	19.5	0.25	2.1
120	100	8.29	0.28	1.0
150	120	3.78	0.28	0.5
200	150	11.08	0.54	2.6
—	200	55.74	3.80	93.7

Similar results were obtained on another slime table.

SLIME TABLE TAILS.

Mesh of Screen		Per Cent. of Total Weight	Assay Value Per Cent. Copper	Per Cent. of Total Copper
On	Through			
120	—	22.8	0.27	3.7
200	120	21.0	0.30	3.9
—	200	56.2	2.67	92.3

On both tables over 90% of the loss occurred in the finest sizes.

Between molecules exists a state of mutual attraction—a particular form of the universal force of gravitation[1]—of extremely small range.

The molecular attraction is sometimes said to be "insensible at sensible distances."[2]

Though limited in range this force is very powerful.

In the case of a water and air surface the sum of attractions on the water side of the surface is much larger than on the air side, where the molecules are much scarcer. The net result is the attraction of each molecule on the surface towards the interior of the liquid.

If the mass of water is sufficiently small it will take a globular shape. The result is exactly as if the outer layer of molecules were an elastic contractile skin. This effect is known as surface tension. The amount of the tension has been calculated by Sir W. Thompson as 75 dynes per lineal centimetre.[3] A good illustration of the immense force exerted by these surfaces is given by Tait.[4]

Two glass plates 6″ square are separated by a film of water 1/200″ thick. The meniscus of water around the edge of radius 1/400″ exerts a pull of between 6 and 7 lbs. in addition to the adhesion over the surface.

If a solid body instead of air is touching the water the number of molecules on each side of the surface of contact will be more nearly equal. If the attraction by the solid molecules is greater than the water surface tension the body will be wetted. Otherwise the solid will be "nonwettable."

Now, consider a solid particle immersed in water. Let it be unwettable. Allow it to come to the surface. The adhesion between solid and water is less than the surface tension of the surfaces, therefore the film of water will be torn from above the particle. The surface tension tends to pull the whole water surface into a spherical shape, hence the particle is ejected and supported by the outer film of water. A hollow will be formed in the water surface to produce hydrostatic equilibrium. The particle will float unless the weight is great enough to overcome the surface tension.

The maximum size of a particle that can float by greasy flotation depends on the surface tension of the water, the adhesion between water and solid, the length of circumference at the water line and the weight of the particle, or the more irregular and flakey and the more nonwettable, the larger the floating particle.

A wetted particle can never come to the surface. Adhesion will always keep a film of water over it and render "greasy flotation" impossible.

---

[1] Sir W. Thompson. Constitution of Matter, p- 49.
[2] Hawkesbury. Trans. Royal Society, Vol. XXVI, p. 1709.
[3] Sir W. Thompson. Constitution of Matter, p. 49.
[4] Tait. Properties of Matter, p. 247.

Now, let the nonwettable particle grow smaller and be immersed. As the radius of curvature decreases the resultant of the surface tension towards the centre of the particle will increase. This resultant plus the attraction between the solid and liquid particles will at some point equal, and then exceed the surface tension of the liquid. The film of water surrounding the solid will be bound firmly to it, and the fine "nonwettable particles act as though wetted, and "greasy flotation for them ceases, consequently there is an inferior limit to the size of floating particles that can emerge. Measurements confirm this.

"Greasy flotation" particles were skimmed from the surface of the water of a table running on chalcopyrite ore. At the same time a portion of the water with its suspended particles was taken in another dish.

The particles were transferred to glass slides and measured with a micrometer microscope. In each field of view a number were actually measured, the size of the remainder estimated by comparison. The numbers of each size were counted. Many thousands of particles were thus measured.

Several days later the experiment was repeated with another lot of ore.

The results are shown on the accompanying curves.

The largest particles are not more than 1/3 of a millimeter. These were flaky triangular pieces. The lower limit appears to be in the neighborhood of .076 mm. Many of the finer particles were carried over with the water when collecting the floating particles and many others would be carried by adhering to the larger particles.

The maximum size of the suspended particles lies between .04 and .03 mm.

No method is known by which a comparison can be made between the sizes found and the theoretical sizes.

"Greasy flotation" has been employed to separate chalcopyrite from its ores. In the MacQuiston process the ground ore is repeatedly poured on the surface of a stream of water. The wettable quartz sinks, the nonwettable floating

The machine consists of four tubes 6'x1'-feet with helical 1½" pitch grooves inside. Tube revolves 3 revolutions per minute. No chemicals are used.[1] It should be remembered that particles too fine to come to the surface are too fine to sink through the surface tension film.

Now, let us consider a bed of wet grains. These grains, if only loosely packed, have a considerable amount of water between them. They easily move on one another. The heavy ores can go to the bottom, the lighter to the top.

If the bed be left undisturbed the particles settle closer together, the water between particles, if they are wettable, becomes reduced to a mere film, which adhering to each particle acts as a cement.

---

[1] Selwyn-Brown. Engineering Mag., Sept. 1908, also Can. Min. Journal, p. 536.

"Hillgaard regards the particles as irregular spheroids, each of which can contact at best at 3 points with other particles, the cause of aggregation therefore cannot be surface tension, independent of the liquid, and the particle being submerged, there is no meniscus to create adhesive tension. Since experiment shows that the flocculative tendency is measurably increased by the *cohesive coefficient* of the liquid, it seems necessary to assume that capillary films of the latter interpose between the solid surfaces and create adhesive tension."[1]

Why unwettable particles should form a solid bed is not so easily seen. The particles touch each other at points. The spaces between are filled with water. The surface tension drags at the films around the points of contact, attempting to assume a spherical shape of surface, and so pressing together and binding groups of particles more firmly than simple adhesion could. Hence a bed of nonwettable concentrates is solider than a bed of wettable feed.

The object of the vibratory motion on Vanners is to take advantage of this superior solidity of the concentrates and to loosen up the feed alone.

A particle of concentrates coming into contact with a layer of previously deposited concentrates is gripped and held. In this respect these tables have an advantage over jerking tables where no solid bed can form.

The tendency of nonwettable particles to stick to nonwettable particles under water has been advanced as the reason for the peculiar suitability of linoleum for table tops.

Linoleum is composed of grains of cork embedded in a matrix of oxidised linseed oil, of which one material is presumed to be more wettable than the other.

The film of water is anchored down by the wetted parts and bridges over the nonwettable to which the nonwettable grains would stick.

If a drop of water is allowed to run over the surface of linoleum the thin edge where the water was on the point of drying would present a jagged appearance if the above mentioned difference of adhesion was present, but only a smooth continuous edge was found, consequently it must be considered that the friction of the surface is the important thing.

Of all liquids except mercury, water has the greatest surface tension. The use of mercury is usually out of the queston because of its density and price.

If some means could be found to considerably raise the surface tension of water, concentration by "greasy flotation" could be applied to many more minerals and would become a most valuable process. Surface tension can be altered by the addition of different substances, thus surface tension diminishes with increase of temperature[1], the addition of fusel oil reduces it enormously.

---

[1] Whiley Agric Analysis, Vol. III, p. 180.

A bubble of air or any gas is nonwettable. Many metallic sulphide particles are nonwettable. If the air bubble touches the particle the water forms a meniscus around both, and the bubble sticks to the particle. If enough bubbles stick the grain will float. This is the basis of most flotation processes.

The plan was devised by C. V. Potter at Broken Hill, N. S. W. Acid acting on a carbonate produced bubbles. It was used on zinc-lead ores. It has been superceded by similar but more efficient processes.

Most minerals when exposed to the weather tarnish. The thin film of oxide alters the adhesion and the particle becomes wetted and the bubbles will not stick. To overcome this difficulty acid, usually crude sulphuric, at the rate of 10-20 lbs. per ton, is added to the pulp. It removes the tarnish. It may to some extent alter the surface tension. Common pyrite separates well with acid alone of less than 1% strength.

Other liquids have the property of wetting some bodies and not others. Among these is oil. It has great adhesiveness for some metallic sulphides, but for wetted surfaces none at all. Water will wet gangue minerals but not the metallic sulphides. If an ore is treated with water first and then mixed with oil, the sulphides become oily, the other particles wet. The difference of surface tensions on the gangue and sulphides is greatly increased. Bubbles, being nonwettable, now more readily attach themselves to the greasy particles.

To complete the operation several methods are employed.

The acid-oil process is as follows: Sands and slimes containing about 18% water are agitated with 10-15 lbs. $H_2 SO_4$ and 1 lb. crude mineral oil per ton of 2240 lbs. The mixers are heated to 120° F. The mixed pulp is then sent through 5×5×5 ft. V spitskasten and the concentrates floated off. A certain amount of calcite provides CO_2 bubbles which attach to the concentrates of zinc and lead sulphides. At Broken Hill the recovery averages 68% of the silver, 80% of lead, 75% of the zinc.[2]

The Krupp process employs heat to expand the bubbles and increase their carrying power. The mixer is a high, narrow cylindrical tank. The flow of concentrates over the top is regulated by the inflow of feed and the outflow of tailings at the bottom. A hot solution of 1% sulphuric acid is admitted through leaden pipes at the bottom.[3]

The Elmore oil process uses an excess of oil, which floats to the surface, carrying the sulphides with it. The oil and acid are mixed in a trough with wooden stirrers. It then passes to separators where the oil and watery tailings separate. The oil is turned into a fast-revolving cylinder. The concentrates cake by centrifugal force on the outer wall of the drum. Excess of oil and water flow over the top.

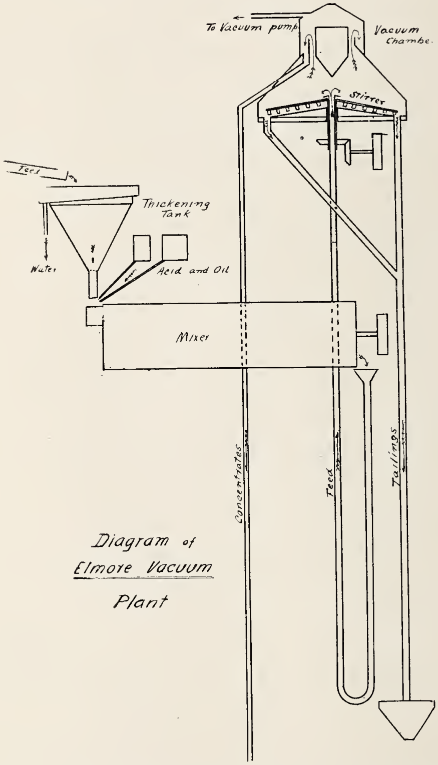
---

[1] Tait, Properties of Matter, p. 247.
[2] Williams. Eng. & Min. Journal, 1908, p. 893.
[3] Eng. Min. Journal, No. 86, 839-42.

The concentrates are removed at intervals.[1]

The Elmore vacuum process which is the most promising of the acid-oil processes, employs a vacuum to expand the air bubbles. Enough air is contained in ordinary water to supply the bubbles under diminished pressure.

Only enough oil is used to wet the sulphide particles—5 to 10 lbs per ton. Acid is added at the rate of 10 to 15 lbs per ton. The pulp is stirred in a mixer as in the Elmore oil process. From the mixer the pulp passes up one leg of a syphon and down the other. The upper end of the syphon is enlarged into a chamber several feet in diameter. A revolving stirrer assists the separation of the concentrates as the pulp passes over the floor of the chamber. A vacuum pump removes the air liberated and preserves the continuity of the syphon. The concentrates descend from the surface of the water by a third leg of



---

[1] Eng. and Min. Jour. Vol. 74, p. 371, Vol. 75, pp. 262, 292.

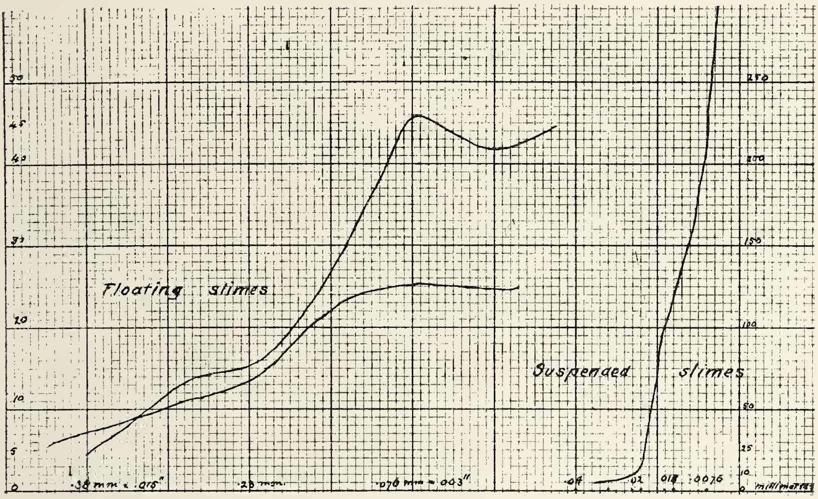
the syphon. The amount of oil used is too small to pay for saving.

This method has a high efficiency, extraction running from 80 to 97 per cent.[2]

Its low working costs render it suitable for low grade ores, having been brought as low as 60 cents per ton.[1]

Another process uses solid greases instead of oil. Crude vaseline is applied by means of a roller and a bath of melted grease to a canvas belt with a woollen face. The belt is set at a steep incline 45° or more and travels upward at a rapid rate two hundred feet or more a minute. The steeper the belt the greater the speed.

The sulphides stick to the grease as the pulp runs down the belt. The rich outer layer of grease is removed by a scraper and falls into the bath of hot grease. The concentrates sink to the bottom, the grease being used over again. Excess of vaseline is removed by a centrifugal separator similar to Elmore's.



A small board 10 feet long, 1 ft. wide with 1" sides and properly stiffened, was used to make tests of this process. Vaseline was liberally smeared over the board. This grease table was set at a slope just sufficient to create a velocity of flow enough to carry quartz tailings along. Chalcopyrite and quartz ore was choke crushed with a Blake crusher. The over size on a 30 mesh screen was rejected. The remainder was mixed and sampled, 1 kilo was weighed out and thoroughly wetted with water. The slimes were poured into a separate can. The coarse particles were poured over the table and repoured three times, each time being followed by a wash of water to clean off the last of the tailings. The surface was rubbed between each pouring to present a fresh surface of vaseline.

---

[1] Literature of Ore Concentration, etc., London.

[2] Can. Min. Inst., 1908, p. 461.

The fines were then treated similarly, being poured over the table 10 times.

Examination of the coarse showed it to contain grains of pyrite so large that the flow of water carried them off the board.

The fines still contained pyrite and so the operation was repeated 5 times more.

Area of board 10 sq. feet, therefore the coarse passed over 40 sq. ft. and the fines passed over 150 sq. ft. of grease.

The tailings were dried screen sized and assayed.

The vaseline was scraped from the board, melted on a water bath and the clear vaseline poured off.

From the concentrates the remainder of the grease was removed by gasoline and the concentrates assayed.

This table gives the results:

	Wt.	Assay Val.	Total copper.
Feed	1000 grms.	4.15%	41.5 grms.
Conc.	103.9 grms.	28.26	30.13 grms.
	6.3 grms.	19.4	

This gives an efficiency of 72.6 per cent. The tailings assay is in the following table:

TAILINGS.

Size of Screen		Weight in Grams	Assay Value	Total Amount Grams Copper	Per Cent. of Loss
On	Through				
40	—	186.51	2.18	4.06	36.0
60	40	314.40	1.41	4.44	39.3
80	60	87.73	0.54	0.48	4.3
100	80	73.70	0.36	0,27	2.4
120	100	30.71	0.41	0.13	1.1
150	120	21.36	0.55	0.11	1.0
200	150	71.05	0.69	0.49	4.3
—	200	102.31	1.28	1.31	11.6

These results show the chief losses to lie in the largest and smallest sizes.

A second experiment was tried with the same crushed ore that had lain exposed to the air of the laboratory for two weeks. The saving was extremely small owing to the oxidation of the surfaces of the copper pyrite.

A fresh portion was crushed as before, sifted through an 80 mesh screen to remove the coarsest grains. The efficiency was raised to 82.3%, most of the loss being in the fine sizes.

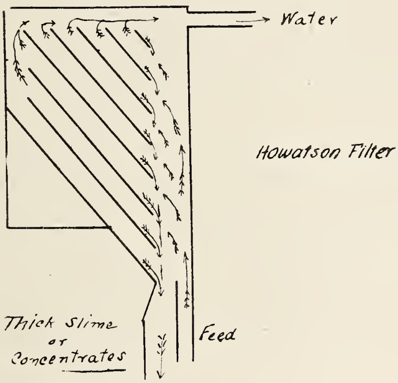
The losses in the fines is, partly at least, due to some of the grains acting as wetted particles.

Because of the similarity of the surface tension actions involved in this process and the Elmore vacuum process it is probable the sources of loss are the same in both.

The flocculative tendency of fine slimes is taken advantage of in the Howatson filter[1], the Durant filter and others. The floccules once formed stand considerable disturbance without breaking up. The finest pulp gives the solidest floccules.[2]

The plup travels upwards and diverges over sloping shelves. The decrease in velocity due to increased space allows the slimes to settle on the shelves. The short distance they have to fall shortens the time required. The agglomerated slimes slide off the shelves and fall through the ascending currents without breaking up.

Other factors beside the density of pulp enter into the settling of slimes. The density and viscosity as they increase reduce the settling rate, though Dr. Barus states the viscosity had no effect on some fine particles in his experiments [3] with regard to the velocity of fall.



Slimes settle notably fast in distilled or hot water, results due no doubt to the reduced sp. gravity of the medium[4]. Others consider the changes too great to be laid to the charge of sp. gravity[5].

By others the retardation is laid to occluded air and small bubbles [6] but in most cases the effect of air is small[7].

Increase of temperature decreases the flocculative tendency[8].

Ordinary temperature changes are sufficient through convection currents to overbalance the extremely slow falling rate of the finest particles[9] but experiment proves that particles protected from temperature changes settle very slowly, and that particles held in suspension for weeks are still of measurable size, that is greater than .0001 mm.[1]

---

[1] Inst. Min. & Met., Vol. 17, p. 311.
[2] Whiley. Agric, Analysis, Vol. 1, p. 180.
[3] Richards Ore Dressing, p. 474.
[4] Nichols. Inst. Min. & Met., Vol. 17, p. 295.
[5] Sulman. Inst. Min. & Met., Vol. 17, p. 312.
[6] Richard's Stamp Milling of Gold Ores, p. 126.
[7] Nichols. Inst. Min. & Met., Vol. 17, p. 320.
[8] Whiley. Agric. Analysis, Vol. I, p. 181.
[9] Ibid.

Sulman as a result of "measuring the angle of contact between liquids and solids found a rise of temperature modified these angles quite out of proportion to the slight change in density due to heat. He considers, therefore, that heat is a factor producing results inexplicable by change in density alone.[2]

There are two explantions of the slow settling of slimes and both are probably true, i. e., the electrostatic theory and the colloidal theory.

The electrostatic theory is as follows: The molecules of water and the particles of solid become electrified, the solids usually becoming negative and the water charged with positive electricity.

The solid particles being charged alike, repel each other and consequently become diffused through the liquid. This probably explains the increase of settling rate due to removing the bottom slimes.

If an electrolyte be added to the water its molecules become ionized into +ve and —ve ions, which neutralize the —ve and +ve charges on the solids and water, destroying the electrostatic repulsion of the solids. It follows that an increasing quantity of electrolyte will neutralize the charges on an increasing number of particles until the whole are neutralized. This is the point of maximum efficiency. If the number of electrolyte ions is further increased the particles become reelectrified and the action is reversed.

The efficiency of electrolytes to settle particles varies greatly with the nature of the suspended substance.

For metallic sulphides 1 part of common salt to 60 water is only as efficient as 1 to 200 for calcium chloride and for iron, ammonia alum, 1 pt. in 90.000 of water. Thus iron am. alum is more than 1,000 times as efficient as salt.

An excellent description of this theory and experiments in connection with it is in Perrin Journal de Chemie Physique Vol. 2 and 3, and Neues Jahr Buch fur Mineralogie, 1893.

An idea of the great difference in rate of settling may be gathered from this table[3]. The ore was Nova Scotia gold quartz.

Electrolyte	**O added**	**Na.**	**Cl.**	**Am.**	**Alum**	**HCl.**	**H_2SO_4**
Per cent. added	0	½	1	½	1	.19	.15
Per cent. settled	22	89	99	97	100	100	100
Time in hours	½	½	½	½	3	½	½

The addition of electrolyte caused the previously invisible particles to agglomerate immediately into visible grains[1]. Nichols states that in the very thin pulps the temperature may be more potent than electrolytes.

---

[1] Whiley. Agric. Analysis, Vol. I, p. 181.
[2] Inst. Min. & Met. Vol. 17, p. 312.
[3] Richards Ore Dressing, p. 1147.

In thicker pulps any cause counteracting the repulsion due to electrostatic condition would be more and more potent as the particles crowd together.

In pulps containing more than 15% of solids the effect of electrolytes and change of temperature becomes rapidly obscured[2].

Mill tests were made to test the possibility of utilizing the increased settling rate in the treatment of chalcopyrite on slime tables.

In the first experiments the ore was mixed, divided into three lots. One part was used to adjust the table, the third part mixed with salt at the rate of 2 lbs. to the ton of 2,000 lbs. The second part was left unsalted. The ore was crushed in a stamp mill, the slimes separated by a classifier and sent to a slime table. Samples of the feed and unsalted tails were taken. The salted portion was then worked over and samples taken as before. A decided gain was found.

In a second experiment the ore was crushed under stamps through an 80 mesh screen and sent direct to the tables. The pulp thus contained a large portion of fine sands.

The pulp was divided by a partition in the launder into two equal portions, one of which went to slime table No. 1 and the other to slime table No. 2.

A pail of strong salt water was set on the launder and arranged to deliver a stream of salty water into either half of the divided pulp.

The salt was first added to the No. 2 table feed, and samples taken from both tables.

The salt was then switched to No. 1 table feed and samples taken. No other changes were made.

By running both tables possible variations due to feed, change of temp, inequalities of salt supply, were eliminated.

	Assay value	Diff. in %	Efficiency
Feed	3.94 % cu.		
No. 1 table, tailings, not salted	1.59		59.6
No. 1 table, tailings, salted	1.53	.06	61.2
No. 2 table, tailings, not salted	2.17		45.0
No. 2 table, tailings, salted	2.07	.10	47.5

On each table the salt raised the efficiency. Salt was used because of its lesser corrosiveness than acid, and also for the ease of obtaining it. Other electrolytes might have given an even better result.

---

[1] Richards. Ore Dressing, p. 1149.

Inst. Mining and Met., Vol. 17, p. 238.

A CIRCLE DIAGRAM FOR THE ALTERNATING CURRENT SERIES MOTOR

It is an established fact that complete and accurate characteristics of an induction motor can be obtained by means of the "circle diagram" of Heyland and others. Taking this diagram as a basis, the performance and other properties of the single phase series motor may be approximately pre-determined.

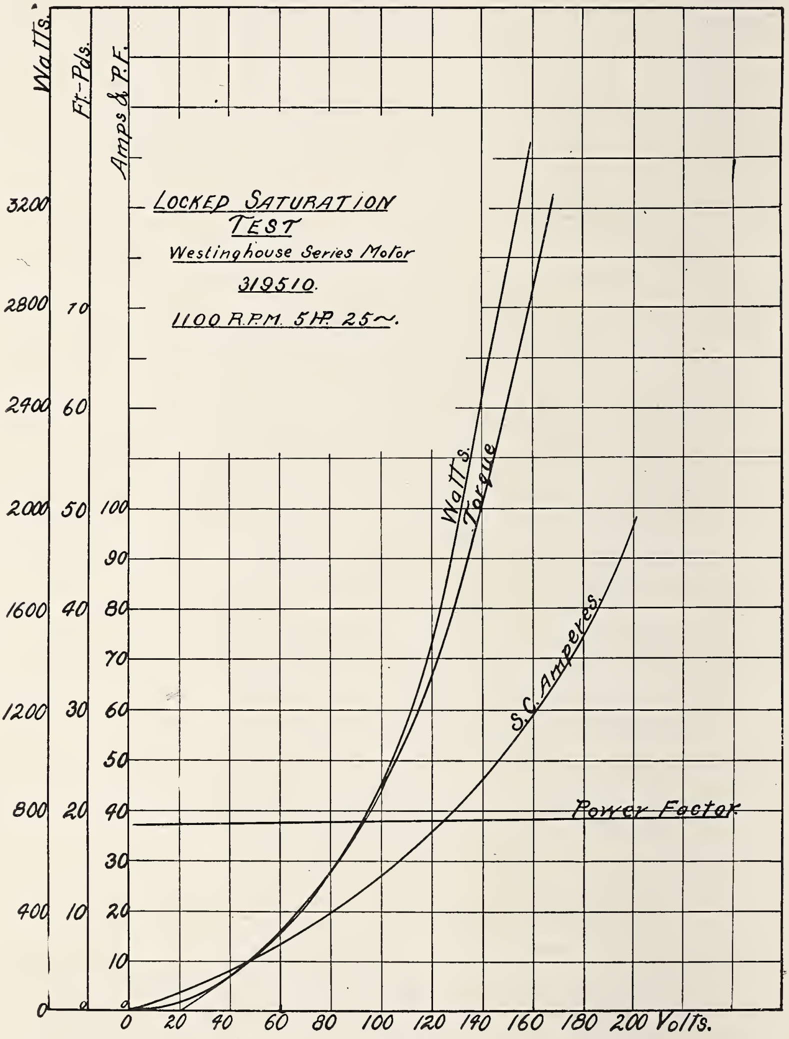


Fig. I.

Construction of Diagram.

To obtain data necessary to construct the diagram, two tests, a "locked saturation" test and a "no load" test are required. For the locked saturation test the motor armature is clamped and reduced voltages are applied. Readings are taken of volts, amperes, watts and torque, care being exercised that the frequency is kept constant at rated value. Plot curves of watts, amperes, torque, and power factor on voltage base and interpolate from the values for results at required voltage. (See Fig. 1.)

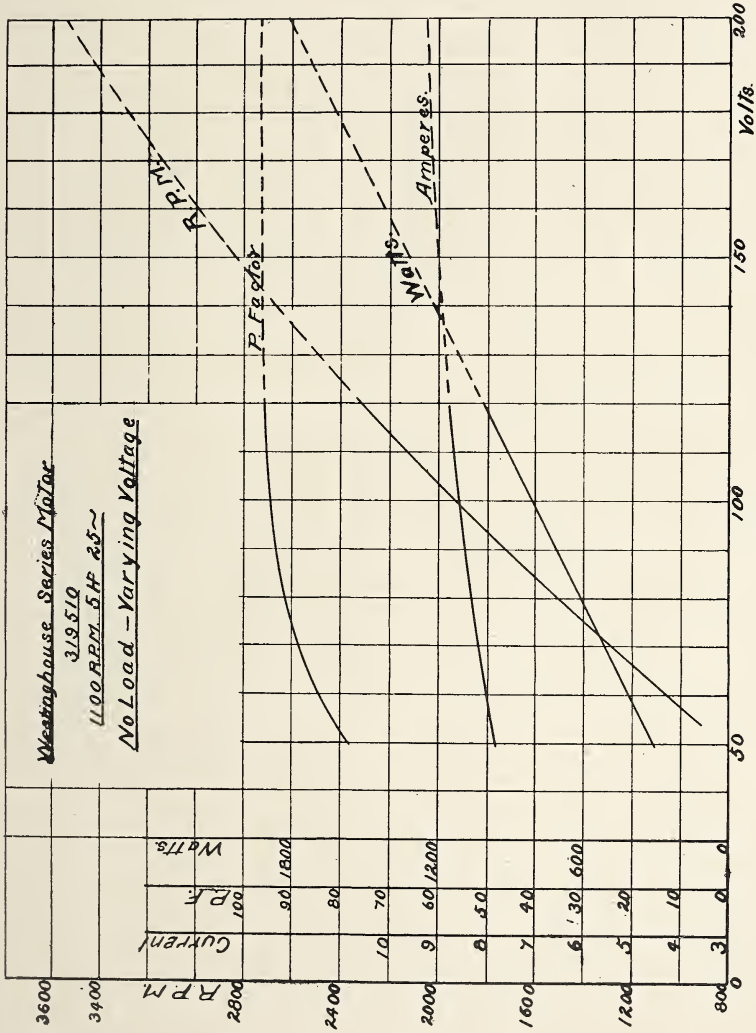


Fig. II.

For the no load test the machine is run light at reduced voltages up to that pressure causing maximum allowable speed. Readings are taken of voltage, amperes, watts and speed. Observations are again plotted (Fig. 2) on a voltage base and interpolations made for data as in the locked saturation test.

To construct the diagram, proceed as in the case of the "induction motor." Assume the horizontal line *OX,* (Fig. 3,) to represent the direction of the current at zero power factor, and *OY* the vertical will be the direction of the *E.M.F.*

From the locked saturation test (Fig. 1) plot to scale the current vector *OP* in proper phase relation with the impressed voltage, the power factor being then represented by the cosine of the angle *YOP*. Similarly from the no load test (Fig. 2) plot to scale the current vector *OQ* in proper phase relation, cosine the angle *YOQ* being the power factor, care being taken that both current vectors are taken at the standard voltage and frequency. Through the points *OQP* describe a semicircle, the locus of the current vectors. Centre *O* draw arc of a circle *HBK* also any line *MN* perpendicular to *OX*.

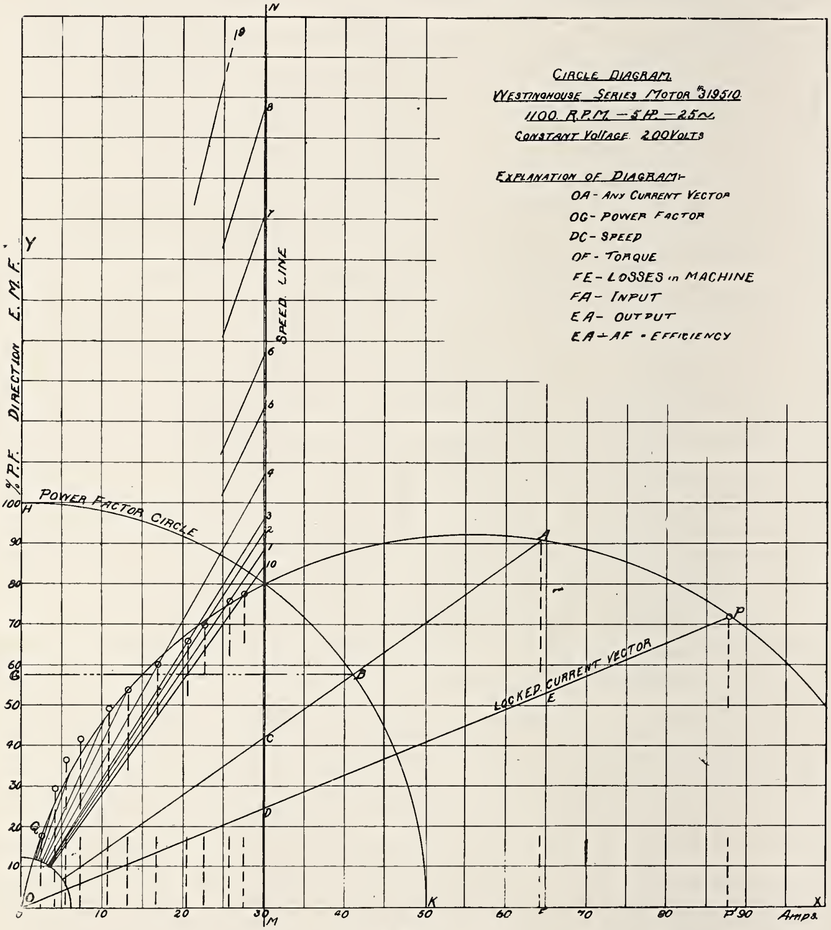


Fig. III

The quantities represented in the diagram can best be shown by a definite example.

METHOD OF USING DIAGRAM.

OA is any current vector at power factor represented by cosine angle YOA. This may be read directly as % by length OG, where the length OH is 100 % power factor. Distances along line MN represent to scale the speed of the armature The intersection of this vertical line MN and the locked current vector OP is zero speed. The vector OQ intersects line MN at 9. The distance D.9. represents the speed of machine at no load, therefore $D.C.$ is speed under conditions existing when OA is the current vector.

The torque obtained in the locked saturation test will be represented by the length OP^1, OF therefore represents the torque under assumed conditions. PP^1 is the energy component of the locked current and also represents the input and in this instance the losses in the machine. For the assumed conditions FA is the total input to the machine FE the losses, consequently EA will be the output, and finally $EA \div FA$ the efficiency.

RESULTS.

In the following table, comparisons are given of the results of an actual brake test and the results obtained from the method indicated in the diagram. The performance curves from both methods are shown in Fig. IV.

LOCKED SATURATION TEST.

Volts	Watts	Amps.	R P.M.	Torque	Power Factor
200	7220	95	0	103.8	38%

NO LOAD SPEED TEST.

Volts	Watts	Amps.	R.P.M.	Torque	Power Factor
200	1792	9.25	3520	0	97 %

BRAKE TEST RESULTS.

Volts	Input Watts	Amps.	R.P.M.	Torque	Power Factor	Output Watts	Effcy
200	7805	47.8	723	50	81.65 %	5135	65.7
	7620	46.0	820	46	82.75	5358	70.3
	7010	41.7	880	40	84.1	4999	71.3
	6625	39.0	930	36	84.9	4758	71.8
	6032	34.5	1030	30	87.35	4387	72.8
	5400	30.0	1180	24	90	4025	74.5
	4940	27.0	1280	20	91.45	3637	73.6
	3650	19.1	1800	10	95.6	2555	70.0
	2942	15.3	2220	6	96.2	1891	64.2

CALCULATED RESULTS FROM DIAGRAM.

Volts	Input Watts	Amps.	R.P.M.	Torque	Power Factor	Outpup Watts	Effcy
200	2845	15	1900	8.3	95.0%	2240	78.5
	3740	20	1652	12.6	93.5	2960	79.0
	4600	25	1418	17.3	92.0	3480	75.5
	5400	30	1232	23.3	90.0	4070	75.4
	6120	35	1048	30.4	87.25	4520	73.7
	6840	40	913	37.0	85.5	4800	70.2
	7450	45	788	44.8	82.75	5020	67.3
	8000	50	684	53.3	80.00	5200	64.8

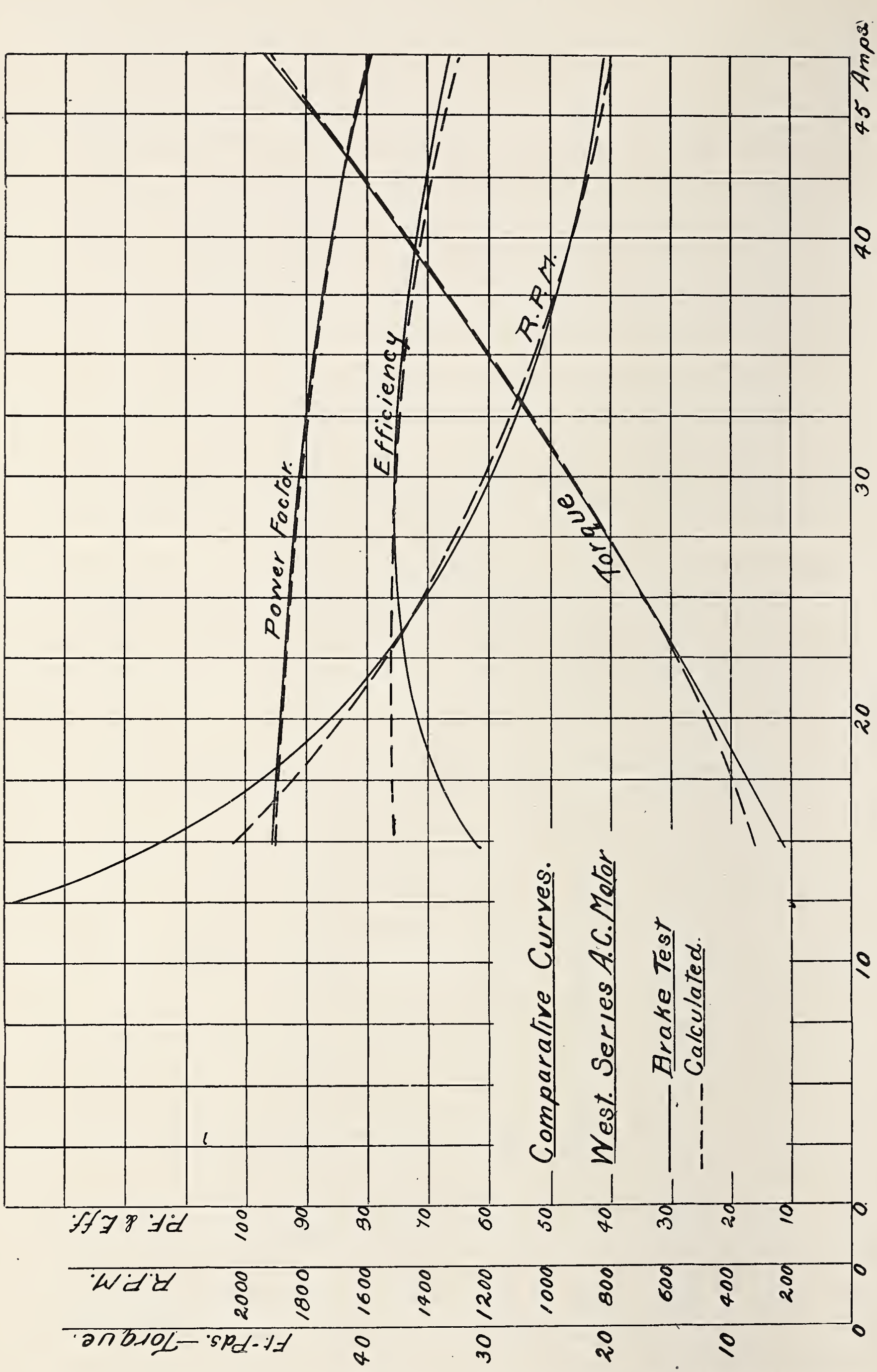


Fig. IV.

NOTE—"Applied Science" desires to express its appreciation for this article to Messrs. Fierheller, Hopkins and Dundass of the Electrical Engineering Staff.—ED.

PURE WATER BY MEANS OF ELECTRIC-OZONE.

R. H. Hopkins, B.A.Sc.

The following article is a brief description of a modern method of purifying water by means of electrically produced ozone.

The plant, which is the first municipal ozonizing one in America to treat the entire water supply of a community has just been installed at Lindsay, some seventy miles north east of Toronto. The town is in the centre of a rich farming district. It takes its water supply from the Scugog river, a sluggish, muddy, weedy stream, which in turn receives its supply, some twelve miles up, from Scugog Lake, on which is located the village of Port Perry, which runs its sewage into the lake.

The town receives its water from mains at a pressure of 60 to 120 lbs. this pressure being maintained by means of a standpipe on a hill at the west of the town, to which the water is pumped from the pump house on the banks of the river just above the town. The filtration system in use prior to the installation of the ozone purification plant consisted of a twelve-inch pipe leading from a crib sunk in the river to a rough filter containing some 18 inches of sand, gravel and charcoal and thence to the pure water tank, from which the water was pumped into the mains. The inefficiency of this method was such that the water had a murky, muddy color, a disagreeable odor and bad taste; besides which the germicidal properties of this filter as shown by tests were practically nil.

In april, 1908, the water commissioners made an agreement with Mr. James Howard Budge of Philadelphia, the inventor of the system, to instal on trial an ozone purification plant. The contract took effect September first; and in the remarkably short time of eight weeks the town received ozonized water. This time would have been considerably shortened but for the unlucky fact that an almost impenetrable blue clay was encountered in excavating for the water and ozone mixer.

This is not the first time that ozone has been used in the purification of water but hitherto the cost has been excessive as shown by the following extract from the report of Mr. I. M. de Verona, M. Am. Soc. C. E. chief engineer of the Department of Water Supply of the city of New York, on a series of tests made by the officials of that city of an ozonizing plant in 1907.

"'The experiments showed that of the amount of K. W. energy used, about one quarter was consumed by the refrigerating machine, one quarter by the transformer and ozonizer, and one half by the compressor. It appeared that the color might be reduced from about 15 to 5, and bacteria from 100 to 7, by the use of about 3,500 grms of ozone per 1,000,000 gals. with an expenditure of about 800 K. W. hr. electrical energy, 200 of which were expended in the ozonizer and transformer.

With electrical energy costing 2½ cents per K. W. hr. (a low price) it appears that under the conditions of the experiments the process was costing about $20 per 1,000,000 gals., of which perhaps $5 represented the cost of the ozone and the other $15 were chargeable to drying the air and pumping it into the water."

This plant did not run a single day without stopping, but these stops with a single exception were all due to defective working of either the refrigerator or air compressor. The one shut-down due to the ozonizer was caused by a preventible short circuit. The stop was only momentary, however, an extra unit being instantly switched in.

The cost for power here, although stated as low, is excessive (especially as this use for electricity is an all day one, which can be stopped for a few hours at peak loads and therefore should get special rates), as the following figures will show:

2½ c. a K.W. hr. = $56 H.P. year, 10 hr. day, 300-day yr.
2½ c. a K.W. hr. = $163.80 H.P. year 24 hr. day, 365-day yr.

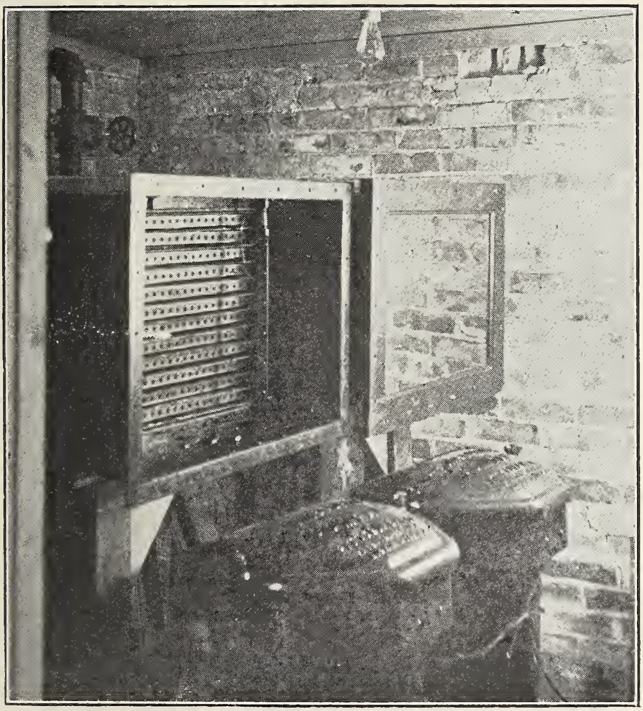
Plant Under Construction, Lindsay, Ont.

Power is supplied in Orillia at $16 H.P. year, 24 hr. day, 365 day year; in Niagara, $12 to $25 a H.P. year; in Lindsay, $25 to $35; and it is expected the rate will be $18.20 per H.P. year in Toronto.

A reasonable cost for 24 hour a day power in New York for this style of service would be 1c. a K.W. hour (it can be produced for less than this there). This would bring the cost of the imperfect system there tested to $8.00 per million gallons. In Lindsay it is 77c. per million, which sum with interest and depreciation on the plant is brought up to $2.75 per million. Slow sand filters cost from $7 to $9 per million gallons and mechanical filters cost $10 to $12.50 per million gallons. The results of the New York test, as stated, were not the best obtainable, owing to the ozone used being insufficient. In Europe the standard is 3785 grms. of ozone per million gallons of water. Here are some of the results obtained at the de Fries plant near Paris, by the official authorities of that city:

Grms. of ozone per cubic meter of water.	Bacteria before ozonization.	Bacteria after ozonization.
2.216	800	2
2.035	850	3-4
1.352	2682	3

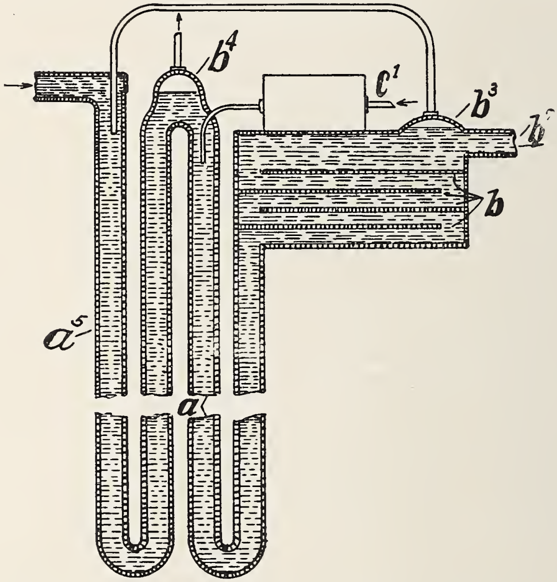
The Lindsay plant consists of a raw water basin Hungerford sand filter, Asperator sterilizer, ozonizer and pure water basin. The filtered water basin of the old plant is utilized, the water passing from these through an 8″ pipe into the surface of the sand in the Hungerford filter, losing about 2″ of head in so doing. This rough mechanical filter is intended to strain out the suspended matter. The suspended matter is excluded for two reasons, first a question of color, as suspended particles always give water a muddy color which can only be removed



Views of Ozonizer

by a filter, as ozone has little or no action on suspended matter other than organic matter and bacteria; second a saving of ozone, as organic matter may to some extent be removed by a filter, and therefore the ozone will only have to act on the bacteria and the dissolved organic matter that passes through the filter.

The rough filter consists of a rectangular tank of reinforced concrete 12 by 15 feet deep sunk in the ground. It contains a series of pipes which gradually enlarge as they join each other, finally terminating in an 8″ discharge pipe. Sunk in the upper sides of these pipes are 130 brass sand valves, which allow the water to pass in either direction but exclude the sand. On these valves there is about three feet of sharp hard sand which accomplishes the removal of the grosser particles of suspended matter. The filter is cleaned by means of a valve so arranged that water from the city mains at a pressure of 60 to 90 lbs. can be passed upward through the valves and sand. The wash water escapes through two valves into the river. This process of washing takes about three minutes and is done every second or third day, depending on the condition of the river.



Raw water enters the pipe a^5 drawing, by suction, unobsorbed ozone from b^3 The waste gases escape at b^4. The current of water in a sucks fresh ozone into itself from the ozonizer c; and after passing around the baffle plates in b, the purified water escapes at b^2.

In flowing through the Hungerford filter the loss in head at 500 gallons a minute is 4′ 8″. It was designed to work at 1000 gallons a minute, but the level of the river during this very dry season has fallen lower than ever before and there is not at present sufficient head to give this large volume of water. Under ordinary circumstances 500 gallons per minute is the pumping rate. This rate, however, is doubled during fires; an auxilliary filter of the same type may be installed to give 1000 gallons a minute at any level of the river.

From the rough filter the water passes into another chamber in which its height is regulated by a butterfly valve and float. Here it flows into an air-tight box of concrete connected to the ozonizer by a 2″ pipe. The water now falls through a number of four-inch pipes, leading to the bottom of a well 30 feet deep, passing in so doing the ends of a great number of small pipes (see diagram for theory). The water by suction thus draws the ozonized air into it; and here is one of the special features of the plant. Other ozonizing plants have used an air compressor to force the ozonized air into the water; and as the compressor has to be worked without lubricants which would otherwise be oxidized by the ozone, such a compressor is a very costly and unsatisfactory machine.

The water and ozonized air now pass slowly upward through a system of baffle plates (see diagram) which prevent the ozonized air from too rapidly leaving the water. The head required to operate this sterilizer when treating 1075 gallons of water a minute is only 20″. If the cost of power and consequently of ozone is high, the partially used ozone after passing from the water, may be collected and used over again. (See diagram.)

The electrical equipment is housed in a small brick "lean-to," 8 by 10 feet, built against the power house. In this building are two 2½ K.W. 60 cycle transformers, transforming from 1040 volts, the town distribution voltage, to 8,000, 10,000 or 12,000 volts, depending on the leads used; a ⅛-h.p. motor driving a small blower to supply air to the ozonizers; and the two ozonizers. t will be noticed that there is no drying apparatus such as is used in European practice, Mr. Bridge having found that the yield of ozone is not increased enough by this to make up for the cost of operating either a refrigerating machine or a mechanical dryer.

The ozonizers (see photo), of which there are two, are quite distinct, in fact each ozonizer, with its own transformer and separate air inlet and outlet, is a separate unit, so that either or both may be operated. Each ozonizer contains 26 electrodes, 13 negative and 13 positive, each protected by its iron fuse. The electrodes are plates of aluminium 20 by 34 inches, and are filled with holes similar to those in a nutmeg grater. By an arrangement of baffles, the insulation being micanite plates and fibre, each little discharge, of which there are five million, encloses a jet of air; and here is one of the fine points of the ozonizers. It is a well known fact that an electrical discharge repels air, and if it were not for the arrangement in the ozonizers the air blown on the discharge would be repelled by it, and not nearly as large a percentage of ozone generated.

The plant as it is at present operated is supplying 4,000,000 to 4,500,000 gallons of water a day. Five hundred gallons a minute are pumped and about 4 h.p. of electricity is regularly used in the ozonizer. This may be increased to 8 h.p. as specified in the contract. The plant is costing the town $7,250; but this cost is low on account of using old filters and excavations. To duplicate it would cost in the neighborhood of $25,000.

The plant to date seems eminently satisfactory, the water after filtration is clear, cold, odorless and in fact looks and tastes like good spring water.

The following is the report of a preliminary report:

BACTERIOLOGICAL REPORT

March 22, 1909.

Report of water receied from Wm. Hammond, Water Commissioner, of Lindsay, on the 18th day of March, 1909.

We have received the following report of analysis of water from this plant. It speaks for itself:

Laboratory No.	Sender No.	Where collected from	Number of Bacteria using N. Agar + 10.0		Strepto cocci	Staphylo-cocci	Colon Bacilli	*Colon oid Bacilli	Chlorine in parts per million
			at 18°–22°	at 37°–40°					
1299	No. 1	**Rain Water**	3800	—	—	—	—	—	2
1300	No 2	**After Ozonizing**	2200	—	—	—	—	—	2

+ = present.
— = absent.

Colonoid bacilli are such as belong to colon group. Bacterial counts are made only when specimens are still in ice and the "time limit" of ten hours has not been run over.

Remarks: The count speaks for itself.

John A. Amyot.
Prov. Analyst.

THE YOUNG CIVIL ENGINEER.

Close of Discussion by E. W. Stern.

To the gentlemen who have so ably and freely entered into the discussion, I wish to acknowledge my thanks and appreciation. They have given us the benefit of their valuable experience and earnest thought; not to mention their time. They have brought to it an intimate and sympathetic understanding of the young graduate engineer's position, as all are college bred men, and have risen from the bottom to the topmost ranks of their profession by sheer ability.

It is my good fortune to know practically all of these gentlemen, and to respect them, not only for their professional ability, but as men. Their ethical standards are of the very highest. They are all leaders in the full sense of the word and are highly appreciated by the community at large. What they have said, therefore, the result of mature thought, and actual experience both as employe and employer, along the very lines which go to make their remarks so very valuable to this discussion, can only be commended by me to your most thorough and serious consideration.

I have only one exception to make. In Mr. Thomson's discussion he states that it is nearly always desirable to obtain the largest salary possible on the principle that the employer is going to give the best work to the highest paid man.

I do not agree with Mr. Thomson in this, nor do other gentlemen who have discussed this paper. My own experience both as employe and employer is that this is not good advice. No better way to become a "floater" could be suggested. Often, when business is brisk and there is a scarcity of well qualified draughtsmen or assistants, a man may demand and obtain a higher salary than he is worth. His position is almost always temporary, for as soon as it is possible to reduce the force, he is among the first to be let go. Furthermore, an employer (if he is a sensible one) will give the best work to the man who is best qualified to do it, regardless of salary.

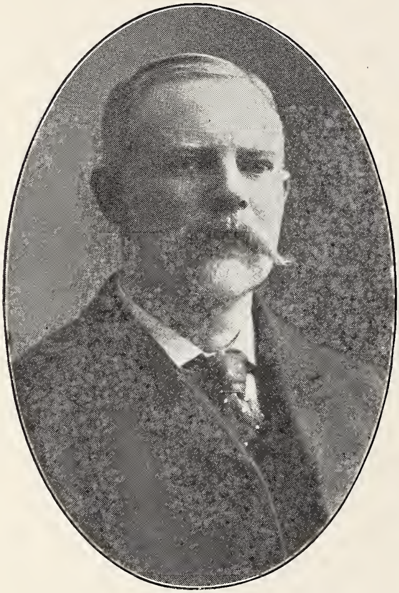
I have not intended to give advice to old engineers but only to the young graduate for the first few years of his career—in his practical post graduate work, so to say—the idea being that the young skipper sailing his craft in new waters, might be benefitted by the experience of the old mariners, as to just what shoals to avoid. He must soon sail his own craft, however, and steer himself.

The time will come when he will be able to master new situations and problems which present themselves, with tact and skill and the confidence born from experience. He will have found himself.

IN MEMORIAM.

James McDougall, B.A., Assoc. M. Inst. C. E.

James McDougall was born at Baltimore, Ont., in 1853. He was educated at Upper Canada College and University College, Toronto, and obtained his B. A. degree in 1880. Having decided upon civil engineering as his future profession, he entered the School of Practical Science, Toronto, in 1881 and graduated in 1884. Subsequently he taught for a short time as a private tutor. He began his professional work under the late Mr. J. T. Stokes, C. E., engineer for the County of York, and was employed on the Welland Canal and on the Canadian Pacific Railway under the late W. T. Jennings, C.E.



Jas. McDougall, B.A.

In 1892, on the death of Mr. Stokes, he was appointed engineer of the County of York, which position he held until his death on 2nd Sept., 1908. He was admitted to the Institute of Civil Engineers, London, England, as an Associate Member in 1906.

In addition to his duties as county engineer he carried on a private practice as a consulting engineer. He was the engineer in charge of the York Radial Railway system and its various extensions—was employed on such questions as the taking over of electric railways by municipalities—was an authority on concrete and reinforced concrete construction, etc., etc. His work was of the best. His ability, tact, good judgment and simple honesty gained for him the respect and confidence of all who came in contact with him in a business way. He combined in a marked degree theoretical knowledge with practical sagacity, kept closely in touch with the latest engineering developments, subscribing for both English and French engineering periodicals. One of his marked personal characteristics was his extreme modesty and dislike for publicity. He never pushed himself nor aided his friends in pushing him. By nature a student, he had the student's fondness for books and was an omniverous reader. I have been told by one of his former class mates in University College, who knew him intimately in after life that he was one of the best liberally-educated men the University ever produced.

While making no pretensions as a critic in literature and art, his tastes were cultivated and his judgment excellent. Among people with whom he felt free he was a delightful talker and a charming companion. He combined in a rare measure strength of intellect with delicacy of perception and refinement of thought. A keen sense of humor served as a shield to his too sensitive nature and saved him from many a trouble. Kindly and generous in disposition he had many friends but few intimate companions.

His memory will long be cherished by those who knew him best.

J. Galbraith

Duncan Sinclair.

Duncan Sinclair was born on Dec. 6th, 1870. He spent his boyhood days on his father's farm at Cheltenham, Ont., and secured his early educational training in the public school of his native village. Later, he attended Georgetown High School, where he secured his senior Matriculation. Following this he taught school for three years. In the fall of '99 he entered the School of Practical Science, obtaining his degree in 1903, and having been president of the Engineering Society during his final year. He first secured employment with the Hamilton Bridge Works, and subsequently with the Canada Foundry and the Grand Trunk Railway at Stratford. In the spring of 1905, he went to New Liskeard, where he became junior partner in the firm of Blair and Sinclair. In 1906 this was changed to Blair, Sinclair and Smith and in 1908 to Sinclair, Sutcliffe and Neelands.

Of the class of 1902, none was more highly esteemed than Duncan Sinclair. His native ability and industry placed him always well up in the lists and his unfailing cheerfulness won for him many friends. In later years when he rubbed up against the world in a community and an environment where opportunities to leave the path of strict rectitude were frequent and tempting, Sinclair always carried himself with the strictest honesty. He played the game fair and his word was as good as his bond. His illness dated from July, 1908, and although the best medical advice was obtained, permanent relief was not to be had, and he passed away on January 5, 1909, at his old home in Cheltenham. He is survived by his widow, formerly Miss Mary Stewart, of Parkhill. Ont., to whom he had been married only a few months previously. His untimely death has taken one whose capacity for work, whose business ability, whose integrity and whose geniality gave promise of a life of great usefulness.

Garnett Rae Jardine.

Garnett Rae Jardine was born near Bowmanville on Nov. 2, 1888. His early school days were spent there, and in Western Manitoba. He entered high school in Brandon, but returned, when 17, to Bowmanville, where he claimed honors, and in his final year tied with a comrade for first position.

Garnett Rae Jardine

While there, he decided to attend the School of Science and enrolled in the fall of 1906. At the close of his freshman year, honors again fell to him, which was only natural, since he seemed happiest in the pursuit of his studies.

Much of his second year was spent in chemical research and laboratory work. While thus engaged he unfortunately inhaled a quantity of nitrogen peroxide gas, which later irritated his lungs to a very great extent. His studies, however, did not suffer lack of attention until scarlet fever confined him to his bed, and, on March 5, 1908—less than a week from his last attendance at lectures—his death was reported among his fellow students. Then it was felt that one of the keenest of intellects and noblest of natures had "crossed into that undiscovered country from whose bourne no traveller returns."

When the present shall have crystallized into the past he will be remembered for his extraordinary ability, good fellowship, and genial disposition. When we think of his exemplary habits, moral character and devotion to high ideals, it helps us to better understand that

> "Death's but a path that must be trod,
> If man would ever pass to God."

W. F. Ratz.

The late W. F. Ratz, D.L.S., whose death through typhoid fever occurred at Ottawa on the 6th February, 1909, was a graduate of the School of Practical Science of the class of 1902.

Mr. Ratz entered the "school" at the early age of sixteen. In spite of his youthfulness he acquitted himself most brilliantly throughout his entire course, graduating with honors and obtaining the T. Kennard Thomson prize in the Department of Civil Engineering.

Immediately after leaving the University he received an appointment in the Topographical Survey Branch, Department of the Interior, Ottawa, where he remained till the spring of 1905, when he was transferred to the Boundary Survey staff, under the charge of W. F. King, Chief Astronomer. It was at this time Mr. Ratz obtained his Dominion Land Surveyor's certificate, heading the examination lists.

His work on the boundary survey was in Southeastern Alaska. In the year 1907 he was engaged on the Stickine River, and in 1908 on the Endicott River.

His work was always carried on with the greatest accuracy. The service has lost a splendid surveyor, and the country a most promising citizen in the death of Mr. Ratz.

Among those who knew him, Mr. Ratz was a universal favorite, and none regret his untimely death, in his twenty-fifth year, more sincerely than do his fellow graduates of the University of Toronto.

PRESIDENT'S VALEDICTORY.

Gentlemen:—I have now come to my last duty as President of the Engineering Society. It is with a feeling of relief that I lay down the responsibilities, and with a feeling of regret that I must sever my connection with a work in which I have been intensely interested and into which I have thrown all my energies. I want to thank your for your co-operation during this past year. I feel that I can truly say, in every enterprise we have undertaken as an executive, we have felt at all times that you have not only approved of our course, but that you were willing to assist us in every way in making the business in hand a success. Much of what has been accomplished this last year can be attributed to your own energies administered at the critical times.

In reviewing the work of the year there are certain features of it which require more than a passing note.

The Supply Department has been reorganized to place it on a sound business basis with business principles as the root of the system. By a new method of keeping an account of the sales and checking stock it is believed we have placed in the hands of the auditors a means of checking the money handled in this branch of our work.

Arrangements have been under way for some time to secure for the Society the sale of text books in our supply department, and I have good grounds for saying that this will in all probability be consummated before the new executive takes over the work. By this means we hope to add another source of revenue to the Society, and also to make it entirely independent of outside assistance. It is thought that, with these improvements, a clerk of supplies could be obtained at a reasonable salary, whose only duty would be to look after the sale of supplies, and this department could then be kept open at all hours of the day.

The present arrangement has been more or less critized, but it seems to me, the chief reason to be urged against it is that it interferes too much with the academic work of the assistant of the paid secretary.

It is hoped also that the revenue derived from this increased business will provide for a larger and better "Applied Science." Throughout this past year it has been our endeavor to keep "Applied Science" up to the standard, and if possible to put it upon a paying financial basis. This journal is one of the most important departments of our work, for through this medium we are kept in constant touch with the graduate body. I think I am safe in saying that "Applied Science" is going to accomplish all that its originators had in view at its inception.

Printed notes of lectures, which have been advocated so frequently in election platforms of recent years, are being obtained, slowly it is true, but nevertheless surely, and no doubt in a few years, will be in use in all departments.

In the Mechanical and Electrical section of the Society a new experiment was tried this year. Excursions were arranged to visit the different manufacturing establishments in and around Toronto and the experiment has proved very successful due partly to the energies of the Vice-President of that section and partly to the assistance given by the Faculty. These excursions could be extended to the other sections and would, in all probability, achieve the same results.

Our sectional meetings have been attended by a fair measure of success. The Vice-Presidents of the different sections have worked hard in their endeavor to make these meetings interesting and instructive, and they deserve credit for their untiring efforts. One feature which has been noticeable by its absence has been discussions on the papers presented; but the incoming Vice-Presidents should overcome this, benefiting by the experience gained by their predecessors. It was thought that the prizes offered in each of the sections at the beginning of the year would have the effect of increasing the number of papers and increasing the interest taken in their presentation. Unfortunately this plan has not had the desired effect this year.

A few alterations have been made in the constitution to suit prevailing conditions. These changes were made necessary by the course of events during our year of office, and we trust that these alterations have made it easier for our successors to effectively and efficiently carry on the business of the Society.

One of these alterations has to do with the elections. This I want to explain. It was found necessary this year to hold the elections partly in the afternoon and partly in the evening, because of the increase in membership, and the University regulation requiring all university buildings to be closed at twelve o'clock. For the future the plan which commends itself, is to have all the voting during the day and then to have a "stag night" at the gymnasium.

The annual excursion, this year, to Buffalo was one of the most successful of its kind in the history of the Society. Over three hundred of the members enjoyed the trip.

The annual dinner, held in Convocation Hall on Jan. 28th of this year, was of more than ordinary importance. It marked the beginning of a closer relationship between the graduates and undergraduates and it also demonstrated to the graduates and our guests the important place the Faculty of Applied Sciences is destined to fill in the engineering world. To the undergraduate it proved that to be a graduate meant to be interested in the wellfare of the Faculty of Applied Science and the Engineering Society. It also had other important results which will benefit this Society and this Faculty. A new record for attendance was established and the event has been characterized as an unqualified success.

An attempt has been made this year to provide accommodation for a reading room in the library, and as a mere beginning covers were provided for the magazines. Of course the accommodation is quite inadequate to our needs but it was thought advisable to insert the thin edge of the wedge at this time. Then when the new buildings are being planned, rooms will be set apart for this purpose.

Much of what has been accomplished during this last year can be directly attributed to the strong Executive Committee which you elected a year ago. This committee has worked earne stly and conscientiously and has devoted a great deal of its time for the welfare and upbuilding of the Society. It has been a privilege for me to be associated with the work of this committee, and I assure you that the executive deserves your thanks.

In conclusion, let me thank the members of this Society for the honor they conferred upon me a year ago in electing me to this position. In giving an account of my stewardship I hope that I have merited, to some extent the confidence they placed in me at that time.

I have much pleasure in presenting to the Society their President-elect for 1909-1910 Mr. D. W. Black.

Yours sincerely

ROBERT J. MARSHALL.

TREASURER'S REPORT.

RESOURCES REALIZED 1907-08.

By cash balance	$329 73
Supply	46 00
Ads. *Applied Science*	411 23
Dinner Account	2 00
Outstanding accounts received	35 75
	$824 71

RECEIPTS 1908-09.

Sales Supply Dept.	$4,522 68
Fees	901 00
Sundries	294 70
Ads. *Applied Science* and Subscriptions	240 63
Grant to *Applied Science*	155 00
Rec. Dinner Account	524 40
	$7,463 12

RESOURCES FROM 1908-09.

226 Orders on Deposit	$ 395 50
Bank balance	99 53
Outstanding due Supply Dept.	95 11
Cost Price Stock	2,319 91
Outstanding, due *Applied Science*	619 09
	$3,529 14

LIABILITIES FROM 1907-08.

Outstanding accounts	$125 32
Printing *Applied Science*	651 28
	$776 60

DISBURSEMENTS.

General expenses	$ 266 69
Supply Dept.	3,912 10
Sundries	716 01
Dinner	1,128 30
Applied Science	563 89
Bank balance	99 53
	$7,463 12

LIABILITIES FROM 1908-09.

Sundry outstanding acounts	$ 145 25
Against supply	913.45
Against *Applied Science*	429 78
Surplus	2,040 66
	$3,529 14

We, your auditors, do hereby certify that we have examined the books and accounts with vouchers of your Society for the year from Mar. 27, '08, to Mar. 27, '09, and that the above statement exhibits a true and correct view of the financial standing of the Society as shown by the books of the society.

It was impossible to make more than a superficial audit of the supply department, but if the system, as now proposed by Mr. MacKenzie is carried into effect this coming year, the system of checking executed by the Treasurer and Vice-President will be more or less of a daily audit on the supply department, and if then a thorough audit was made at the end of the year, the system of accounting would, in our opinion, be all that could be desired.

S. R. CRERAR
R. S. DAVIS,
Auditors.

Toronto, April 15, '09.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published Monthly during the College year by the University of Toronto
Engineering Society.

BOARD OF EDITORS

K. A MacKenzie, B.A.Sc. '06	Editor-in-Chief
W. J. Boulton, '09	Civil and Arch. Sec.
L. R. Wilson, '09	Mech and Elec. Sec.
A. Duff, '09	Mining and Chem. Sec.
R. J. Marshall, '08	Ex Officio U. T E S.

Associate Editors

H. W. Price, B.A.Sc., '01	Mech and Elec.
P. Gillespie, B.A.Sc.,	Civil and Mining
M. C. Boswell, M.A , Ph.D., '00	Mining and Chem.
W. Treadgold, B.A., '05	Railway

Advertising Committee

S. S. Gear, '08
T. H. Crosby, '09
R. H. New, '10
L. E. Jones, '11

Subscription Rates

Per year, in advance	$1 00
Single copies	20

Advertising rates on application.

Address all communications :

Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont.

Editorial

This issue completes the second volume of Applied Science and closes one of the most successful years of the Faculty of Applied Science and of the Engineering Society. Several decided advances have taken place in each. The new laboratories for thermodynamics and hydraulic will be practically complete by fall and fourth year difficulties will be to a great extent solved. Keen disappointment is felt, however, as the impression grows that the Board of Governors are not going to take any steps towards a new Engineering Building.

We wish to take this opportunity of thanking our contributors for the valuable assistance they have afforded.

Next year plans are already laid to make Applied Science bigger and better than ever. The co-operation of all the graduates is earnestly requested.

THE STUDY OF ENGLISH LITERATURE IN AN ENGINEERING COURSE

W. B. REDFERN, '08

(1). While engaged in academic work as a student of applied science and engineering, one sometimes considers the advisability and practicability of introducing into our curriculum a course of lectures on the study of English literature, and bearing on this very important question, these few remarks are directed. Let it be understood that this article is not one of protest or dissatisfaction, but rather is it one of suggestion on account of interest in the general welfare of this faculty.

The curriculum at the present time gives us a comprehensive and thorough training in that particular branch of engineering that we are studying, almost entirely from the mathematical and scientific standpoint. We study mathematical subjects as Algebra, Trigonometry, Analytical Geometry, Calculus, etc., and we study scientific subjects as Statistics, Dynamics, Astronomy, Thermo-dynamics, Hydraulics, Theory of Construction, etc. Such a course of studies tends to develop a highly accurate type of mind—a type of mind that wishes and must know the why and wherefore of everything—a type of mind that demands facts, absolute facts, and the causes and effects of the same. As the vast natural resources of Canada become more evident day by day, just so the need for men capable of developing these resources with the best possible results for Canada also increases. And further a country whose population is growing by leaps and bounds is certain continually to present new mathematical and scientific problems for the solution of which all the powers and intellects trained to perfection to deal with such subjects are emphatically needed. Consequently in the efficient and economical development of these resources such a type of mind as above mentioned is required, and will find great scope for the exercise of its faculties.

But need that type of mind be purely scientific and mathematical? Not at all—it may also combine the culture and breadth derived from studying subjects of a nature, not mathematical and scientific, but of a nature entirely different—literary and etymological. In the study of classics and the modern languages entirely different faculties are trained and developed than in the study of the accurate subjects of mathematics and science. In the former case the mind is not constrained to keep within a certain well defined limit of thought and argument, but it may branch out and devote its energies in channels of thought and argument where there is a much greater freedom and latitude. There are no hard and fast limits, but there are excellent facilities for the exercise and development of the imaginative and creative powers, the training of which are even eventually so necessary for engineering design. A piece of translation or an idea may be expressed in a dozen different ways, all equally good but yet following no well defined limits of expression. Of course, no thought whatever is entertained of introducing classics into a course of engineering, although even a transitory knowledge of them is of some value, yet practically the same faculties are involved and developed in the study of English literature as are involved and developed in the study of classics and of the modern languages.

Graduates in engineering upon entering the practical work of their profession wish to guard against the curse, or "bête noir" of professionalism to-day—narrow-mindedness. We hear that it is so easy to "get into a rut" and so difficult to get out of it. The surest and best way of avoiding narrow-mindedness is by frequent indulgence in desultory reading. If one confines himself in his reading to engineering subjects only, naturally his mental vision will not only carry him beyond the horizon of engineering problems and of engineering accomplishments. Hence, if our studies while at college are as comprehensive and inclusive as possible, our mental vision will be extended far beyond the horizon of our profession, so that we may see and understand things that otherwise would remain incomprehensible and imperceptible to us. It is as if we ascended the mountain of culture and knowledge farther, by so doing greatly extending our mental scope and vision. Our sympathy for humanity would be broadened, and instead of being students in engineering only, we would become students of affairs, and accordingly we would be more serviceable to the community in which we live. Therefore if a course of lectures in English literature were introduced into our curriculum, and greater intellectual discipline and culture that we would acquire would develop in us a much higher mental efficiency, a deeper sympathy for humanity and a much broader outlook on our profession.

Francis Bacon has said,—"Reading makes a full man." And it is not only essential that we should read, but it is even more necessary that we should understand what we read, that we should "digest" what we read. To be able to select the best literature written by the greatest and best men and women who have ever lived, and to be able to understand it requires guidance, training and study. Also to recognize and appreciate a good author's particular style of writing and to detect and discriminate his fine shades of meaning requires guidance, training and study just so surely as these are required in the design of a bridge or in the location of a railway.

Where, then, are we to look for this training and study, so essential and important? Most of us have not attended a collegiate institute long enough to acquire this knowledge and culture. So up to the present time it has been necessary for all who were desirous of becoming conversant and familiar with English literature and the English language to do so entirely apart from their academic work. Then again our academic work requires so much time of the average student that very little remains to be devoted to these outside studies, unless he is an omnivorous reader and is determined to find time "come what come may." A stream cannot rise higher than its fountain. Consequently to remedy this defect, to meet this need and to place our graduates on a higher pedestal in public opinion, the study of English literature would do much to attain this end.

Also even from a purely professional standpoint, great personal benefit would accrue to those who have an opportuity of studying English literature and the English language in connection with their college work. Some one has said that language is a "vehicle of the engineer." It is certainly indispensable in his profession. He must be familiar with it, because he must use it every day. In drawing up specifications, in writing reports, in engineering correspondence and in many other ways, he must always have the language at his command. These then are other important reasons why this departure would be desirable and advantageous.

In conclusion, since we are now an integral part of this great university, working in conjunction with the other faculties for its common good, and since a four-year course for graduation is about to supplant the present three-year course, could it not be amicably arranged to introduce into our course in Engineering and Applied Science a series of lectures on English literature for the good of our faculty and for the good of the University as a whole? The time is opportune. If not, why not?

A CRUISE—A RETROSPECTION.

HYNDMAN IRWIN, '09

[Note.—The class of '09 needs no further mark of distinction. Its curve is high and prominent on the efficiency-time diagram of the Faculty of Applied Science. But before falling down the stairs for the last time, our regard for the other years necessitates a portraiture of this Chapter of the Order of the T-Square.]

On a fair autumn morning in 1906 the renowned class set sail upon the sea of college life in the channel of Applied Science. Our first assemblage in an upper deck apartment was for instruction regarding the manipulation of the lead pencil and the two-foot rule. During the initial week we raised the old flag of yellow, blue and white; and later chose as our captain, "Ginnis" Johnston. On a pennant at the stern was our "Che hee."

Barely had we put forth to sea when, without warning, the crew were called to arms to decide ocean supremacy. This resulted in our being gloriously victorious, the sacrifice of

EXECUTIVE OF GRADUATING CLASS

O. T. G. Williamson   C. Hughes   H. W. Tate   G. Morton   W. S. Collinson
C. O. Hay   T. H. Crosby, Pres.   Dr. W. H. Ellis, Hon. Pres,   G. R. Workman   W. J. Johnston

breath and clothing being nothing compared with the glory of the beautiful new war balloon, which was finally forced to enter our domain through a window of the engine room.

The ship was manned by two hundred and eighty-eight tars. At the end of the first voyage, however, a few were induced to remain behind, enticed by an easy landing in Real Estate, a comfortable resting place in an Arts harbor, or a pleasant (?) outlook from a Medical haven. Although the prospect was not entirely one of pleasure, it has not proved a tedious journey by any means. It may be that a few sought pleasure only in the trip. Moreover, it was rumored upon decks that one considered it too lonesome, and changed to a canoe that was built for two. Any one of the boys in our navy will testify, however, that there has been a great deal of fun and pleasure, apart from hydraulics, as applied to the incoming freshmen, or experimental optics, as studied from the upper windows, the incident ray being cast upon pretty forms that harmoniously float by, casting reflecting rays, normal to the focal plane. The main cabin has often been the scene of many amusing incidents especially on the event of the election of officers, when we were frequently honored by the presence of the Admiralty, smoking cherry pipes with us.

After our first furlough, we again embarked, under Captain Campbell, with Dolly Black as first mate, Billy Carlyle as purser, and Cy Danks as our holy man—two hundred and five souls in all, with arms trembling from the many hearty hand-greetings following our five months' leave of absence. Our work about the ship was intercepted here and there by welcomed theatre nights, football and hockey games; while the annual dinners and engineering excursions created a lively interest in the affairs of the college fleet.

Alas! We did not all survive the severe annual April hurricanes, and many were lost in the storm. One hundred and seventy-three of us answered the roll-call when we next headed seaward. We rejoiced to have Crosby piloting our craft assisted by Hay and Workman, with Wilson, Bolton and Duff working vigorously at the helm.

On our journey together we have met many friends and many enemies. With the latter we have had not a few encounters. The barge "Epistaxis" has oftentimes required a reprimand, and so too, a foreign squadron consisting chiefly of blue helmets and large buttons; while we have several times found it necessary to turn hostile towards sister ships belonging to our own flotilla. If we have ever suffered defeat, we have forgotten it, as the truest of subjects should, leaving a record of complete victories.

During the trip we have had many narrow escapes. A shoal that was troublesome, although not dangerous, was Thermodynamics; the Scylla that threatened the destruction of our bark was Spherical Trigonometry: the constant shooting of electricity from a rosy sky kept the bravest of us in fear and trembling, (and the hungriest of us from assailing our hardtack.) Geometry—analytical and descriptive—proved a dangerous coast if approached too closely; and we have been wafted from our course many times by chemistry fumes.

Although three years is not a very long time in which to gain fame and honor, still we have done so. At the Intercollegiate meets the Science battleships have always had a solid reinforcement from our ship. The Mulock and other cups, have in turn held our mutual joys and tears. We have furnished many of the players in the great teams in football and hockey. Besides, does not the Pride of Cobalt really belong to us?

What we as a class have not learned in our three years of ocean riding, is hardly worth knowing. We know now, that if little is put into study, much cannot be expected. It is simply the working out of the law of conservation of energy.

As for our leaders, they have cheered us on through waves dark and mountain high, and have gained for us the name of being the best mariners that ever manned a ship. And yet, each captain has made his mistakes. His senses were frequently numbed, in dull weather, by moaning fog horns, which proved to be Harper or Cooch, asking a question, or calling for lights, in the middle of a soporiferous discourse. When he warned us that a storm was brewing, it was generally Hagerman brewing mischief. At all events Ginnis, our star ladder scaler would climb the mizzen mast, or go below, in hopes that there might really be something brewing. Or when our musician, Kettle, began to sing, Fate so likened the music to the wind whistling through Doc. James' whiskers that the captain would send them both below, never forgetting that whistling is an ill omen among seamen.

As for our captain of the past year, a page from the log book describes him thus:

"When Manning the ship he was always Kean, but would never Goad us on toward uncertainties. He frequently granted the crew his permission to visit their Holmes, choosing a season in which neither Frost nor Blizzard could mar the pleasure of their holiday. Whenever Sara wandered from sight, the captain would touch a Bell to summon a Workman, whom he would send to Hunter. Then he would Walker about on deck, where he could Vatcher. If he should be down for a Gray snooze and get a cobb Webb in his eye, he would get Crosby degrees, his anger almost immediately subsiding into thoughts of a Greene nook among the Trees on a shady Hill side, with an issue of 'Black and White' to while away the hours. He did not Carrie a Gunn his only weapon for defence being a Key."

We have always been noted for our good behaviour, progressiveness, and curiosity—and generous, even in regard to the Sophomores, although they have not such a high opinion of us, a reflection on their taste. We have always done our part in trying to convince the press that we are of the Faculty of Applied Science, rather than of "Applied Silence" and we are grateful to the Sophomores for their aid.

Thus we have sailed, the golden sunlight, the blue ocean, the white wave crests ever being foremost in our minds. Too soon we leave the pleasant scenes, but all go to knock at the same door—that of the office of Mr. World. When he, grim, as Father Neptune, asks us who and from what craft we are, we need not hesitate to reply:

"Toronto, Toronto, Toronto Varsitee!"

And when he proceeds to inscribe our names in the log of the great ship, "The Future," the shades of Chezy and Rankine, and Kerchhoff, and Berthelot, will, for the moment, step aside, and silently weep in the shadow of Remorse, while our hearts will join with dear old College-day enthusiasm, in a mighty

Chee hee, Chee he, Chee ha, ha ha!
School of Science, Naughty nine,
Rah! Rah!! Rah!!!

The attention of all our readers is again drawn to the list of graduates, whose address we have been unable to verify, which appeared in the February issue. Some of these we have located, but the addresses of the majority are yet unknown.

APPLIED SCIENCE

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Vol. II - New Series

November, '08 to April, '09

PUBLISHED BY
THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY
ENGINEERING BUILDING
UNIVERSITY OF TORONTO, CANADA

INDEX VOL. II, NEW SERIES.

The Young Graduate and the Profession of Mining Engineering. H. E. T. Haultain 1
Preliminary Studies in Connection with the Development of Hydraulic Power. H. G. Acres 15
Copper Anodes in Chloride Solutions. Saul Dushman 22
The Design of Canal Diversion Weirs on a Sand Foundation. W. G. Bligh, M. Inst. C. E. 27
The New Thermodynamic and Hydraulic Laboratories 38
Address. E. W. Stern 41
Address. Robt. Mond 47
A Plea for the Business Training of the Engineer. R. A. Ross, E. E. 53
Notes on Brick and Brick Piers. P. Gillespie, B. A. Sc., and W. G. Swann, B. A. Sc. 57
Interpole Motors. F. R. Ewart, B. A. Sc. 79
The Young Civil Engineer. E. W. Stern 89
A Note on the Relation of the Mining Engineer to the Public. H. E. T. Haultain 97
Plate Girder Web Splices. C. R. Young, B. A. Sc. 99
Insulating Testing. E. M. Wood, B. A. Sc. 110
Some Recent Advances in Electro-Chemistry. S. Dushman 118
Fertilizers and Their Manufacture. F. K. Harris 124
Applied Science Dinner. A. D. LePan, B. A. Sc. 139
The Engineering Graduates. C. H. Mitchell, C.E. 148
History of School of Practical Science. W. Hodgson Ellis, M. A., M. B. 155
History of the Applied Science Buildings. C. H. C. Wright, B. A. Sc. 159
The Needs of the Faculty of Applied Science. President R. A. Falconer 163
The Engineering Society of the University of Toronto. T. H. Hogg, B. A. Sc. 167
Address. Dean Galbraith 170
Transmission Line Formulae. T. R. Rosebrugh, M. A... 187
The Determination of Latitude. L. B. Stewart......... 191
Discussion—The Young Civil Engineer. H. W. Hodge, R. B. Stanton, D. M. Eidlitz, L. L. Brown, T. H. Alison, J. H. Kennedy, T. K. Thomson 205
Aluminium. J. A. McKenzie Williams 218
Water Meters. J. J. Traill, B. A. Sc. 231
Practical Methods of Concrete Construction. C. G. Cline. 236
Cement, Its Manufacture and Chemistry. E. A. Hassan.. 241
Notes on the Concentration of Slimes. F. C. Dyer...... 257
A Circle Diagram for Alternating Current Series Motor. Messrs. Fierheller, Hopkins, Dundass 270
Pure Water by Means of Electricity. R. H. Hopkins 275
The Young Civil Engineer—Discussion. E. W. Stern .. 281
In Memoriam. J. McDougall, D. Sinclair, G. R. Jardine, W. F. Ratz 282
President's Valedictory 285
Treasurer's Report 288

FIRST of all, it is essential for the young civil engineer to be well equipped with a good and thorough technical training. Without it, he will soon find his limitations and his efforts will be confined to "rule of thumb" methods. I have had acquaintance with a number of eminent civil engineers who had a meager technical training, but in every case these men possessed some unusual and extraordinary compensating characteristics. The same men, without any question in my mind, would have been preeminent with a thorough technical training. It is taking extremely long chances for the young civil engineer or any one else to anticipate his success, using as his gauge the exceptional men I have noted.

Provided, that the young civil engineer's good fortune in youth has denied him those luxuries of wealth which ruin self-reliance and that his college work has been thoroughly and efficiently done; provided, that he has reasonably good health with an ordinary head and applies himself honestly and conscientiously along definite lines instead of scattering his energies, and seeks not the line of least resistance; provided, that he always earns more than his salary, the same being his employer's measure of his qualifications for promotion, and that he does not form the habit of chasing ten dollars a month more salary when he is gaining valuable experience; and provided also, that his early and tender recollections keep his sympathies warm and that he pushes his men by well directed kindness and not by fear:—I will show you within fifteen years' time after his graduation, a man who is courageous in his own convictions, who possesses a tried, admired, and sterling character, and who is a prime mover among the men of his profession.

LINCOLN BUSH,

Formerly Chief Engineer Delaware, Lackawana
& Western Railway

ROBERT W. ANGUS, B. A. Sc.
Professor of Mechanical Engineering

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 23 NOVEMBER, 1909 New Series Vol. 3, No. 1

EUROPEAN ENGINEERING LABORATORIES.

ROBERT W. ANGUS, B.A., Sc.

Professor of Mechanical Engineering

During the past summer the writer had the pleasure of visiting Germany, Switzerland, England and Scotland and made it a point to see the engineering laboratories in Brunswick, Hanover, Berlin, Dresden, Munich and Darmstadt in Germany; in Zurich in Switzerland, and in London, Birmingham, Newcastle, Edinburgh and Glasgow in Great Britain.

In Europe, more especially continental Europe, the engineering laboratory has been brought to a great state of perfection so that probably the very best in the world are to be found there. To get even a superficial acquaintance with these one would need to spend a very considerable amount of time and energy, and I very much regret that my time was so limited that it was impossible to study the different institutions as I should have wished. It soon became evident that I must not only omit a number of the Technical Schools altogether, but also that the available time must be devoted to my own special work almost entirely, and it was necessary for me to confine my effort largely to the laboratories in hydraulics and mechanical engineering; i. e., heat engines and boilers and other special mechanical work. This article therefore deals almost exclusively with laboratories used in connection with the above special subjects.

With regard to the schools visited, it should be stated that an especial effort was made to visit the most notable in the different countries. It must not be inferred, however, that only the least important were omitted, because after it had been decided that it was essential to visit certain places, geographical location combined with other circumstances determined those that must be omitted, and some places of excellent reputation had therefore to be left out.

An account of these laboratories will now be given mainly in the order in which they were visited, and as Germany was the starting point the schools in that country will be described first.

German Technical High Schools.

The Germans are a very thorough and industrious people who believe in doing well whatever they attempt to do. One is not therefore surprised to find that they have been very thorough in the matter of technical education and that they have established engineering schools of the very highest order.

But the development of these schools is not due alone to the characteristics of the nation, but probably quite as much to the great change in the occupation of the people which has occurred in the last few years. In a report on the German Technical High Schools made in 1903 by Dr. Rose to the British Government, it is pointed out that in 1871 the population of Germany was 38,000,000, of whom only about 15,000,000 were in the various industries, the remainder being engaged in agricultural pursuits. In 1900 the population had increased to 58,000,000, of whom about 38,000,000 were engaged in the industries while the number in agricultural pursuits was slightly less than in 1871.

It will be self-evident that the nation which is to have a healthy industrial growth must at the same time properly prepare her people for their opportunities in this regard and must train her men to develop the industries in the best possible way. The importance of engineering schools in this connection is well known and Germany has not been slow to realize this and has established within the last forty years no fewer than ten Technical High Schools for the teaching of engineering and allied sciences. These schools are located at Aachen (Aix) Brunswick, Berlin, Darmstadt, Dresden, Hanover, Karlsruhe, Munich, Stuttgart, and Dantzig, cities pretty well distributed over the Empire, many of them also being located in important industrial districts. The number of these schools is being increased from time to time as occasion demands.

It is to be noted that the above list includes only the Technical High Schools and not the great number of universities and schools of various other kinds which are engaged in a somewhat similar line of work. The term "Technical High School" must not be misunderstood in this connection, as it designates an entirely different class of institution from that to which the name is applied in this country. In Germany the name is applied to the real engineering school, the students in these being of similar standing to regular university students and the courses of instruction being somewhat more advanced than engineering courses here.

The amount of money expended on the establishment of these various schools has been very great and the annual contribution by the State for maintenance is also liberal. It is difficult to get definite information on these points but so far as could be learned the expenditure for buildings and equipment at Berlin

(Charlottenburg) would exceed $2,500,000, but of course this is far the largest institution of its kind in Germany. At Hanover the expenditure for similar purposes has been about $500,000, at Brunswick the steam and gas engine laboratory alone cost about $75,000, while all the buildings at Dresden and Darmstadt, both sets of buildings being new, have cost $1,300,000 and $1,500,000 respectively.

The cost of maintenance of these Technical High Schools is also high for various reasons, the most important of which are probably: (1) that the schools are very completely equipped and kept fairly well up-to-date; (2) that there are a great number of instructors and (3) that the fees are comparatively low. The number of students per instructor (including professors, lecturers and assistants) in very few cases exceeds twelve and in many cases is as low as nine. According to the reports to which I have referred, the annual State support to the various Technical Schools varies from about $178,000 in Dresden, $98,000 in Stuttgart, $92,000 in Hanover, to about $50,000 in Darmstadt, and the total to five of these schools in one year exceeded $470,000. The balance of the money required to maintain these institutions is received from students' fees and other sources, the above figures giving only the support received from the State.

An opportunity offered itself to learn something relative to this matter about Dresden where it was found that the annual grant for apparatus and supplies for the steam, gas and hydraulic laboratories alone was $3,000.

It may be interesting to state that for the year 1907-08 the Faculty of Applied Science of the University of Toronto cost the State about $66,000 (allowance being made for fees received) and the total invested in buildings and equipment in engineering would not exceed $700,000.

The German people have not been slow to take advantage of the facilities offered along the lines of engineering education for the total number of students in the nine older schools would considerably exceed 16,000. In Berlin alone there were nearly 5,000 students in 1901-02, in Munich in 1905-06 about 2,800, while the present attendance at Darmstadt is nearly 2,000, at Brunswick about 500 and at Hanover 1,500.

These statistics are of some interest in showing how technical education has taken hold in Germany, and as I went from place to place and saw many new buildings and new additions to old ones I was fully impressed with the fact that the people are alive to their opportunities in that line.

That the courses given in these institutions are varied and thorough is at once evident on glancing at any of the "Programmes" issued by them. I might give one illustration, that of the Munich Technical High School, as the calendar for 1906-07 is at hand. The courses there are: (1) Civil engineering, in which there are three divisions—(a) civil engineering; (b) agricultural civil engineering; (c) surveying; (2) Architecture; (3)

Mechanical engineering which is sub-divided into (a) mechanical engineering; (b) electrical engineering; (4) Chemistry; (5) Agriculture. All these courses extend over four years with the exception of Surveying and Agriculture, both of which are three-year courses.

Space will not be taken to quote the list of subjects in each year, but these would indicate more advanced mathematics than is given in this country, and indeed an examination of the entrance requirements for fully-qualified students shows that the latter are much more advanced when they enter than the matriculants here. A fairly large proportion of these entering have a considerable knowledge of both analytical and descriptive geometry, and of the calculus, and are well advanced in the general subjects.

The absence of shops and shopwork is very noticeable in the German Technical High Schools, as these shops are very common both in Great Britain and America, scarcely any institution in the latter two countries in which mechanical engineering is taught being without them. As there is considerable discussion on this question of university shops continually being heard, careful attention was paid to this point, but I was unable to find a single school in Germany with these shops, the opinion apparently being that the proper place to learn shop practice is in the shops of manufacturers, and some experience in this class of work is practically always demanded before graduating, in many cases a year of work in a manufacturing plant being required.

The money which would otherwise be invested in the shops is thus devoted to laboratory equipment.

With this general introduction I shall now proceed to describe some of the schools in detail, and as I went to Hanover first I shall begin with it.

Hanover.

The Technical School at Hanover was founded in 1831 as a higher trades school, was made a Polytechnic School in 1847 and was raised to the grade of a Technical High School in 1879.

An old castle situated in a very beautiful park has been so remodelled as to accommodate this school, but, fine and imposing as this edifice is, it is not so well suited to the needs of engineering as might be desired. However, with the rearrangement of the interior and the addition of a new part to the rear, the building has been made to serve its present purpose very well.

I was informed that there were about 1,500 students, and as there are over thirty-five fully qualified professors and more than this number of assistants, lecturers, etc., the instruction should be fairly thorough. Lectures begin at 8 a.m. and stop at 7 p.m. and the students meet in large class rooms holding over a hundred, the idea of subdividing the classes and repeating the lectures being apparently foreign to Germany. The practice of lecturing to large classes seemed to prevail in all the schools visited.

The laboratories in this institution are not so large as I had hoped, but the apparatus is well arranged and is apparently all used. The mechanical laboratory contains a belt tester and several similar devices, a complete suction gas plant and several gas engines, a 10 h.p. de Laval steam turbine, a triple expansion steam engine, a piston pump, several boilers, and considerable other apparatus. Nearly all of the machines are specially arranged and set up for testing.

The hydraulic apparatus is contained in two buildings, in the one are most of the turbines and pumps, of which there are several types, while the other building contains a long open channel and also a fairly large Francis turbine and a pump.

The open channel is of some interest. It is about 260 feet long, 5 feet wide, 4 feet deep with a suppressed weir at one end. The channel is used for making experiments on current meters, etc., and also for the testing of ships' models, a special car, motor driven, being employed for the purpose. This car is arranged to run at uniform speed and an observer riding on it may obtain all necessary data for a given experiment.

What impressed me most about Hanover was, however, the marvelous collection of models, and I am doubtful if the number of these would be less than 10,000. There is a model of everything one can think of and they seem with characteristic thoroughness to have determined to leave nothing out. There are models of various riveted joints, pin joints, bridges, roofs, turntables of various design, cranes, switches, canals, ships and their parts, steam engines, valve gears, locomotives, mowers, reapers, water wheels, windmills, threshing engines and separators and many other things, as well as many from the Reuleaux collection. Models are also used to show various industrial processes, such as the casting of various ornaments as perfectly as possible, and illustrations showing how silver frogs, snakes and other small animals can be made an exact copy of the real creatures are exhibited. Small mills are at hand to show how wire is drawn, and there are so many things that one is led to wonder who ever can have the time to look at even a few of them.

I felt very strongly that while these things were of interest to the casual visitor, they were of very little help in the way of instruction and represented largely a waste of time and space from the latter point of view. The models are of considerable interest, but are usually too complicated, small and delicate to be useful.

Brunswick.

The next place visited was Brunswick, a city with a population about one-half as great as Hanover.

The Technical High School here is not so large as the one already described although it was established about two years earlier. The school has now complete courses in all engineering branches and it is under state control, receiving an annual grant of about $56,000. Lectures begin about the middle of October and close at the end of July with vacations for Christmas, and Easter, making a total of about one and one-half months.

There are here about twenty-three fully qualified professors besides many other professors, and assistants, and there are about 500 students.

The main building is not very large and the mechanical laboratory is in a separate building about a block away from the main one. The latter contains the Rector's office, the collection of models and the electrical, physical and other laboratories.

The electrical laboratory is not large and is in the basement, being used by third and fourth year students. There are several galvanometer rooms and a number of machines are available for testing work.

The collection of models was small compared with that of Hanover, but there would be several hundred illustrating various devices and mechanisms.

The mechanical laboratory, in which I was principally interested, is as already stated, in an entirely separate building a short distance from the main building, and is in charge of Prof. R. Schottler whom I had the pleasure of meeting and who is a man of some note. The building is fairly new though not large, and is bright and well built, and cost with its equipment about $75,000.

In addition to a small repair shop the laboratory contains a number of valuable machines, such as a 60 h.p. triple expansion horizontal steam engine fitted to work with steam, having 300 deg. superheat. The valve gears are all of different types; the cylinders are jacketed, jet and surface condensers are provided, and in fact every arrangement is made to provide facilities for experimental work. The machine was sold to the school at cost.

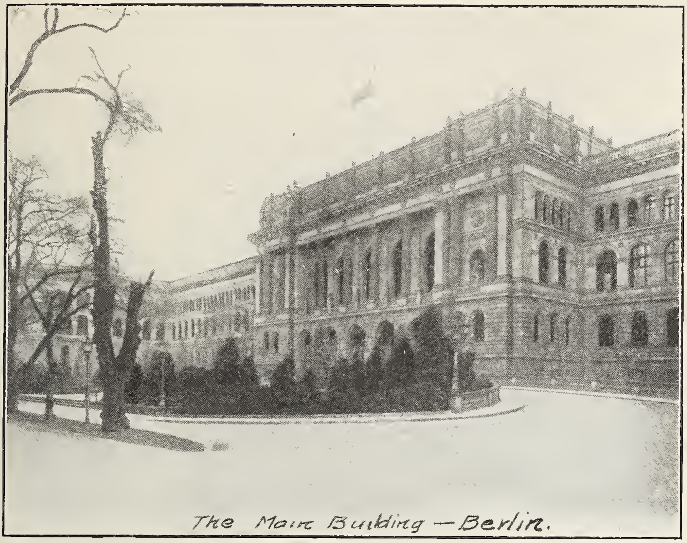
Amongst other apparatus the laboratory contains a small suction gas plant and engine, several other types of gas engine and devices for measuring the flow of steam and air.

Special attention has been given to the boiler room which contains a boiler for high pressures and a superheater capable of giving 380 deg. superheat. A special chimney is also available and all kinds of recorders for temperatures, draft, flow of steam, etc., have been installed, making the equipment quite complete in this respect.

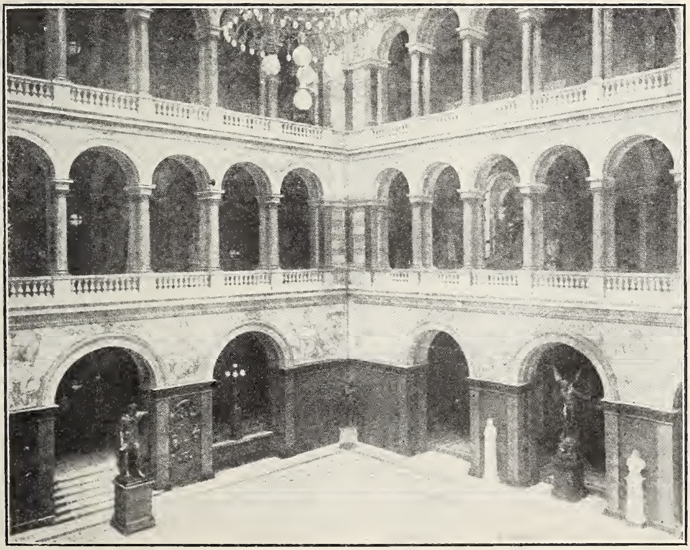
Berlin.

In both Hanover and Brunswick the opinion was freely expressed that in order to see the best Technical School one must go to Berlin, and as this institution is well known to us in America my anxiety to get there increased daily, and it was with considerable expectancy that I reached this great German city.

Berlin has a population of about 3,000,000 people and is probably the greatest commercial and manufacturing city in



The Main Building—Berlin Technical High School.



Interior Main Building—Berlin.

Continental Europe. The manufactures include large numbers of locomotives, engines, dynamos, etc., and here one finds enormous shops, such as those of the Allgemeine Electricitats Gesellschaft, with a working capital of $25,000,000 and 13,000 employes; the Berlin Maschinenbau Aktien Gesellschaft, a very large concern, having special residences erected for its men; Siemens and Halske; the Borsig works, employing 6,000 men and turning out 450 locomotives yearly in addition to many engines, pumps, etc., and many other very large shops. This city is also the capital of Prussia, is the residence of the Kaiser, and the seat of the Imperial Government.

Here then, in this great city in the midst of so much business and progress one naturally expects to find a first-class engineering school and one does not expect too much, for the Royal Prussian Technical High School is in many respects by far the greatest in Europe, and doubtless also in the whole world. Passing out through the delightful Tiergarten one sees on crossing a small stream the massive "Hauptgebaude" or main building, a magnificent structure nearly 750 feet long and about 290 feet wide with a floor area exceeding 330,000 square feet.

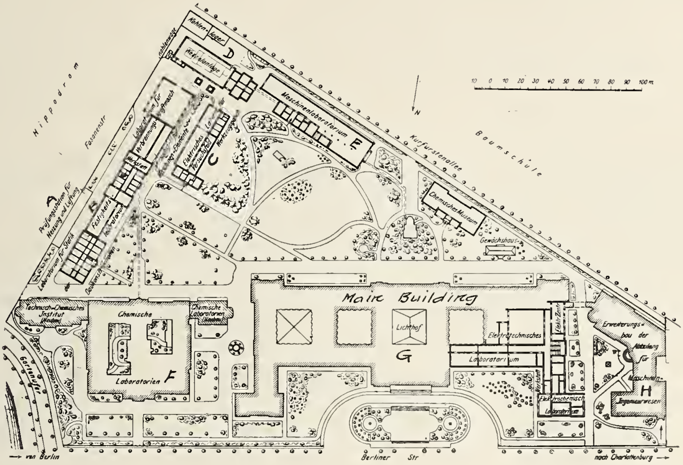
To appreciate fully the grandeur of this building one must visit it, for it is so customary to see engineering schools plain and with very little adornment that one seems to be in a strange atmosphere in this grand place. The building was erected in 1878-84 and is richly decorated with busts and sculptures of such noted men as Gauss, Eytelwein, Schinkel, Redtenbacher and many others, amongst whom it was a pleasure to see Watt and Stephenson. In front of the building are monuments to Alfred Krupp and Werner Siemens. Some illustrations are given of the general appearance of this building.

This Technical High School had its beginning in 1799 as a Royal Building Academy, which was combined in 1879 with a Trade Academy established in 1821. Since 1879 it has borne its present name. On the celebration of its one-hundredth anniversary in October, 1899, the Kaiser granted the school the right to bestow the degree of Doctor of Engineering, a degree first conferred upon Prince Henry of Prussia (*honoris causa*).

There are about fifty-five fully qualified professors besides many assistants, private lecturers, etc., making a total teaching staff of nearly two hundred. There are nearly 5,000 students in attendance, of which number about 80 per cent. are fully qualified. Nearly one-half of the students take the mechanical and electrical course, a fact not surprising in view of the great amount of manufacturing done in Germany.

The Berlin Technical High School, like other Prussian Schools of the same class, is under the control of a Rector and Senate. The Rector is elected annually by the votes of the professors, but his election must be approved by the King of Prussia.

Returning now to the buildings, it will be seen from the plan of the grounds that almost every laboratory has a separate building of its own, the main building being used for the collections of models, lecture rooms, museums, professors' rooms, draughting and other rooms of like nature, some laboratories and the offices of the institution. There are thus ten buildings, viz:—1, The main building, already mentioned; 2, A building for mechanical engineering; 3, A chemical building; 4, A building for experiments on heating and ventilation; 5, A building for testing materials and gas engines; 6, An electrical laboratory building; 7, A building for steam engines; 8, A boiler house; 9, A chemical museum; 10, An hydraulic building. These buildings also contain the laboratories for belt-testing for gas and oil engine and automobile testing; and for the testing of the power required to drive machine tools.


Kohlen-lager
Kohlenwage
D
Kesselanlage
Hippodrom
Fasanenstr
Laboratorium für Verbrennungs-Kraftmasch
Werkstatt
Elektrisches Versuchsfeld
Laboratorium für Werkzeugmaschinen
C
Maschinenlaboratorium
E
A
Prüfungsstation für Heizung und Lüftung
B
Festigkeits laboratorium
Laboratorium für Statik
Technisch-Chemisches Institut (Neubau)
Chemische Laboratorien
F
Chemische Laboratorien (Neubau)
Gartenufer
→ von Berlin
10 0 10 20 30 40 50 60 70 80 90 100 m
N
Kurfürstenallee
Baumschule
Chemisches Museum
Gewächshaus
Main Building
Lichthof
G
Elektrotechnisches Laboratorium
Elektr-Zentr
Werkstatt
Elektrochemisch Laboratorium
Erweiterungsbau der Abteilung für Maschinen-Ingenieurwesen
H
Berliner Str
nach Charlottenburg →

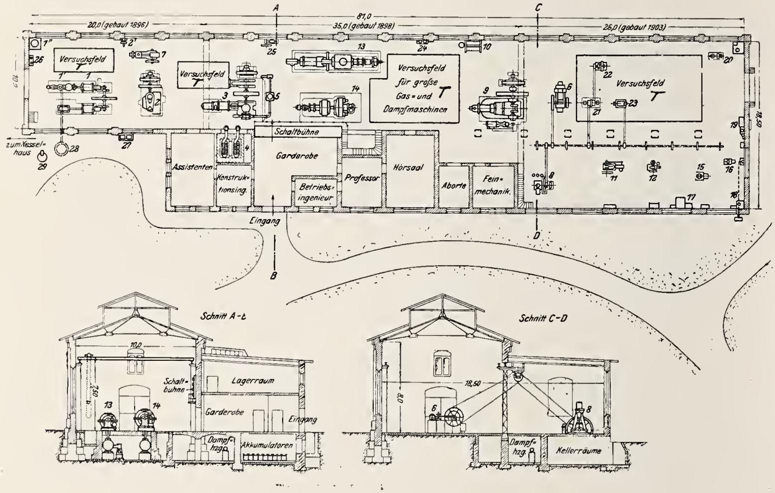
Plan of Berlin Technical High School Grounds

Starting from the lower left hand corner and going up the side of the triangle the first building, A, is the laboratory for heating and ventilation research, the next, B, is for strength of materials and gas engine and automobile testing, C, the electrical laboratory, D, the boiler house, E, the engine laboratory, F, the chemical building, G, the main building, H, the building for mechanical engineering.

In such an institution it is evidently impossible in limited time to look carefully into all the laboratories, so that it was possible only to glance through many of them in order to leave proper time for the machine, gas engine, belt testing and hydraulic laboratories, which will now be described in some detail.

(a) The Engine Laboratory. The building containing this laboratory which was erected in the years 1896, 1898 and 1903, (see figure), is 365 feet long and of width varying from 33 feet to 60 feet, the clear height of the main portion being 26 feet. It is well lighted throughout by very large side windows as well as by others in the roof and the whole main part is served by a travelling crane of five tons' capacity. Some of the engines are used for light and power, but as there are so many of them in the building no difficulty seems to be experienced in getting any machine desired for experiment.

The laboratory contains a horizontal cross-compound engine of 60 h.p., directly connected to a pump and all parts specially arranged for testing; a 220 h.p. quadruple marine engine complete with condenser; a 150 h.p. triple-expansion engine for superheated steam; a 300 k.w. Brown-Boveri Parsons turbine; a 200 k.w. turbine by the Allgemeine Electricitats Gesellschaft, Berlin; a 40 h.p. Woolf locomotive type engine and boiler; several types of air compressors of good size; a 150 h.p. Deutz suction gas engine; a number of gas and gasoline engines and a Borsig refrigerating machine. In connection with the machines described there are necessary condensers and pumps, gas meters and all conveniences for testing, and nearly every machine drives a dynamo which is used to produce the load for experimental work. Friction brakes are not considered as reliable as electrical loads, so that the former are not used to any extent.



Das Maschinenlaboratorium der Technischen Hochschul-

The Engine Laboratory

1 1' Horizontal engine and pump, 2 Quadruple expansion engine 220 H-P. 3 Triple expansion engine 150 H.P., 4 Superheater, 6 Wolf locomotive type engine, 7 Air compressor, 9 Suction gas engine 150 H.P., 13,—300 K. W. Parsons turbine, 15—200 K.W. turbine, other numbers refer to small machines T are test and research floors. The dimensions are in meters.

This laboratory also contains a number of dynamometers of various styles, apparatus for testing nozzles and orifices, and several fairly large testing floors. All pipes are placed under the floor either in trenches or in the basement which extends under part of the laboratory and provides room for some of the condensers and pumps.

This laboratory is well adapted to research work on account of the large size of the machines, and some very valuable work has been done, results of which are published in German periodicals.

It should be stated that the descriptions of the apparatus are not complete, and in such an article as this it is possible merely to mention the more important machines.

The laboratory is under the direction of the well-known Prof. Josse.

(b) The Gas Engine Laboratory. This laboratory, which is in charge of Prof. Riedler, is designed especially for testing gas engines and automobiles, although as previously stated there are a number of gas engines in the engine laboratory just described. The space available for this work is over 170 feet long and varies in width from over 40 feet to about 70 feet, the height being about 25 feet, and all the light being obtained from the sides. The whole of the building is served by a 10-ton travelling crane.

The laboratory contains a 200 h.p. suction gas engine with dynamo constructed by the Vereintige Maschinenfabrik, Augsburg. This engine, which is four-cycle and double-acting, has the latest type of valve gear, and is well adapted to testing. The gas for this engine is made by suction gas producers, of which there are two of 200 h.p. each, located in a separate building, the gas being led over to the laboratory in pipes.

In addition to the above there is a 40 h.p. Korting engine; a 25 h.p. Korting oil engine; a 20 h.p. Diesel engine; several other engines; special apparatus for doing research work on explosive mixtures; numerous gas meters, etc. The engines are all equipped with dynamos which are used to produce the load.

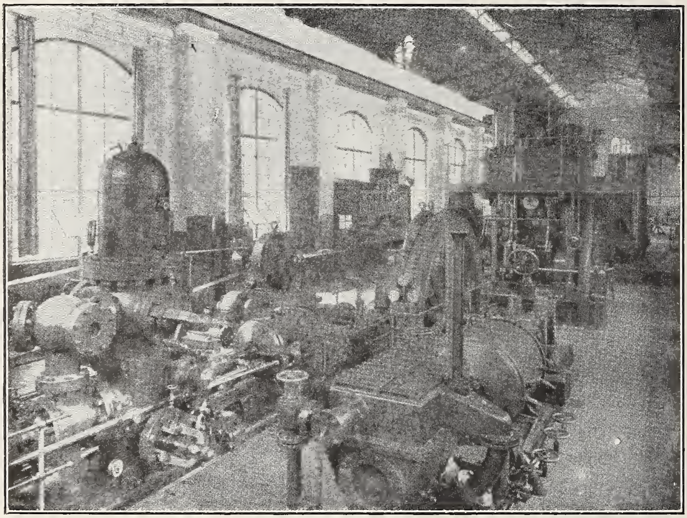
A very interesting feature of this laboratory is the automobile testing plant, designed for testing the horse-power and tractive force of automobiles of all sizes and powers up to 200 h.p. The power of the engine is determined by placing the automobile on a dynamometer driven by the back wheels of the latter, which dynamometer may be adjusted to suit any size of machine. Power is absorbed partly by means of dynamos and partly by Prony brakes, the former being very easily adjusted to give any load desired with great precision. The tractive force is also measured by a special device which cannot be explained here for lack of space.

That this automobile testing plant is in great demand was evidenced by the fact that there were five or six machines waiting to be tested when the laboratory was visited.

There are also testing floors available for other purposes, space being left below these so that access to the lower side of the floor may be easily obtained.

(c) Laboratory for Testing Belts and Machine Elements. This laboratory is about 23 feet wide and 90 feet long, and contains various machines for testing the friction of journals, the holding power of friction clutches, and for similar work connected with the elements of machines. There is also a belt-testing machine capable of testing pulleys 8 feet in diameter, driving a belt as wide as 16 inches. The machine is driven by two 100 h.p. motors which may run at any speed from 200 to 600 r.p.m. Rope pulleys, 6 feet in diameter with four grooves may also be tested on this machine.

The power applied to the belts is measured at the motor and the power delivered, as well as other data relative to the working of the belt, obtained by suitable means at the driven end.



The Engine Laboratory—Berlin.

On this machine in addition to the work on leather belts and various kinds of ropes, very valuable experiments on the steel driving bands now in use in Germany have been made, and with a machine of this size reliable information may be obtained on full-sized specimens instead of on the small models which must be used in most schools.

(d) Laboratory for Heating and Ventilation. I regret that I have been unable to get any material description of this laboratory. The apparatus is very elaborate and complete and a description is soon to be published. This laboratory is about 500 feet long and 20 feet wide so that it is quite extensive.

(e) Hydraulic Laboratory. This laboratory, which is illustrated here is situated some distance from the other buildings in order to bring it beside a natural stream of water. The stream in question is the Landwehr canal, which is used by barges in the city of Berlin and which joins the river Spree about a mile distant.

Adjacent to the hydraulic laboratory for the Technical High School is the large channel installed by the Government for making tests on ships' models, etc.

In almost all cases hydraulic laboratories situated on natural streams are smaller than those not so situated, because in the latter case a very considerable amount of room is occupied by the large pumping machinery required for the supply of water for turbines of the reaction type, and also because experimental artificial channels must be provided in the buildings to take the place of the natural channel outside.

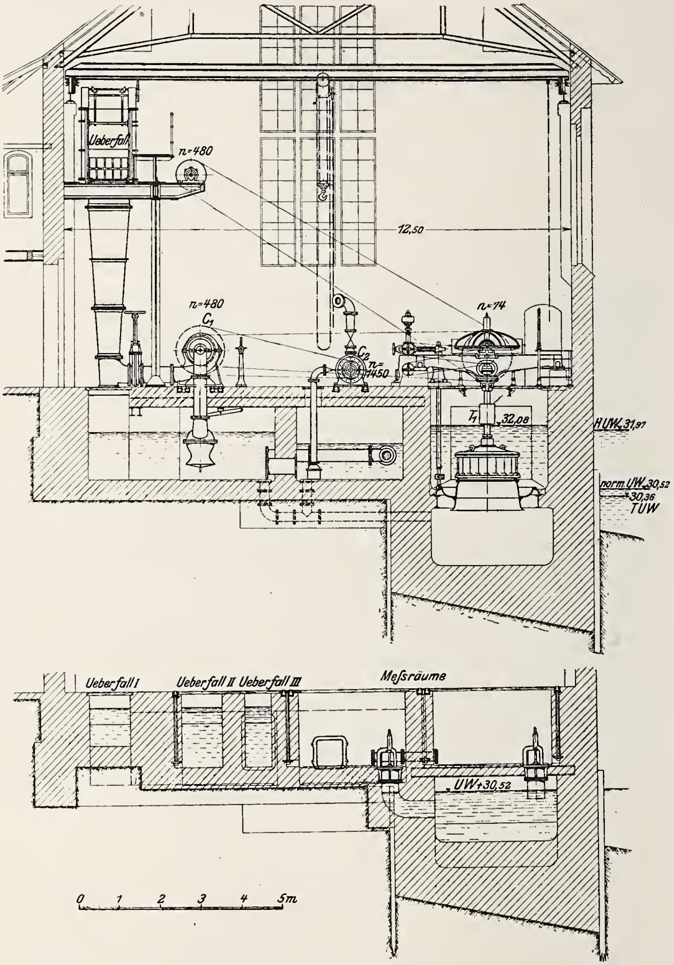
The above statement is true in general of the hydraulic laboratory of the Technical High School at Berlin which occupies a building over 60 feet long and about 58 feet wide, but also includes a channel outside about 180 feet long. It is in charge of Prof. Ernst Reichel.

The power obtained from the stream of water is used in driving a turbine with vertical axis made by J. M. Voith, of Heidenheim, for experimental purposes. The available fall is only about 5 feet, but there is a flow of about 85 cubic feet per second, so that the turbine is of fairly large power. It runs at a speed of 74 revolutions per minute and is equipped with a good turbine governor and a brake for measuring the power, but the wheel may also be used for driving the pumps, etc., in the laboratory, if desired. Numerous experiments are made on the wheel and facilities are also provided for the testing of wheels of other makes. The discharge water is measured by a method fairly common in Germany but apparently not used in this country so far as I am aware. On account of the low head available it was deemed inadvisable to use a weir, which would mean the loss of a part of the available head, in this case seriously reducing the latter.

The cross section of the tailrace is rectangular and of uniform section, and a screen of light material impervious to water is made, which is placed in the stream in a vertical position and normal to the direction of flow. This screen is supported on light frictionless rollers, and as it nearly fills the channel the velocity of the screen gives the mean velocity in the cross-section if the screen is properly designed and supported.

This method of measuring water appears to be accurate, and is very convenient, although it cannot be used in any irregular channel nor in a channel of shallow section. In the latter case the screen can scarcely be made to show the average velocity in the stream because it must in all cases be kept some distance above the bottom of the latter, and hence it is not properly affected by the bottom velocity, the screen thus moving at a faster rate than it should.

On account of the small natural head available a second turbine has been installed to which the water is supplied by a centrifugal pump, and in connection with this there is a long steel channel about 3 feet wide, 6 feet high and about 55 feet long, supported near the roof by means of steel columns.

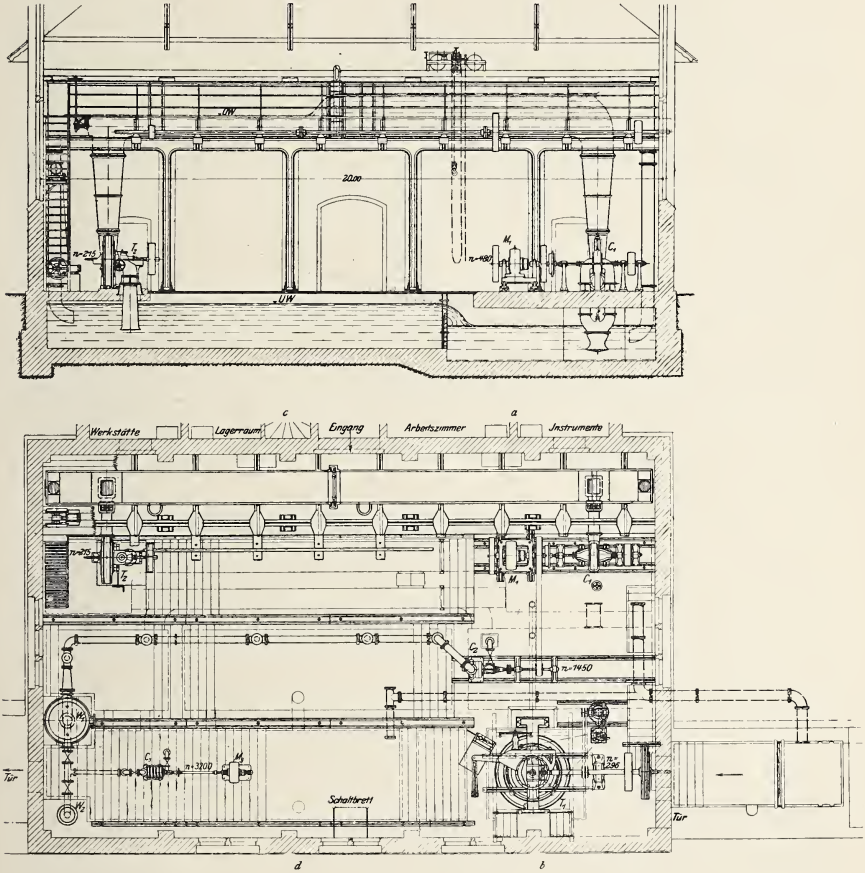


Hydraulic Laboratory

T_1 40-h.p. Voith turbine, C_1 Gehauer pump, M_1 electric motor, T_2 Voith turbine for 20-foot head, C_2 Weise and Monski pump, C_3 and M_3 Jaeger six-stage pump and motor. Measuring channels below the floor are shown. Dimensions are in meters.

Water is supplied to this channel by a centrifugal pump built by Gebauer and having a capacity of nearly 9 cubic feet per second against about 24 feet head. The water flows down the channel and after passing over a weir where it is measured, is delivered to a Voith spiral turbine of the full capacity of the pump.

The laboratory further contains a Weise and Monski four-stage pump for 33 feet head and about 0.7 cubic feet per second; a six stage Jaeger pump for 650 feet head; various motors for driving the pumps; three fairly large measuring canals under the floor; a large vessel for pressure work, and various other devices for measuring jets and determining the resistance of pipes, etc.



Hydraulic Laboratory.

Every facility is offered here for reliable research work and the laboratory is rather crowded. Commercial turbines are also tested here and up to the present time fifteen have been tried; in such cases the working head, the speed and the discharge are all automatically recorded simultaneously on one instrument.

The apparatus for this laboratory cost about $23,000, exclusive of the channels, etc., made in concrete under the floor.

This brief description shows that this great school is well worthy of careful study and indicates that the laboratories present exceptional opportunities for research work. Good advantage has been taken of the facilities offered and the institution well deserves the prominent position it now occupies amongst the leading Technical Schools of the world.

In a later issue of Applied Science the writer will give descriptions of some of the other great European laboratories.

SPARK DISCHARGES

H. S. FIERHELLER, B.A. Sc.

This phenomenon was in all probability the first electrical evidence studied by scientists. Franklin in 1750 proved its electrical nature but the early experiments and results do not possess more than historical interest, since reliable apparatus was not available at that time. Improvements in the methods and equipments for research have since then been in order, so that to-day the general characteristics of spark discharge are well understood.

There are many forms of discharges between electrodes but the disruptive discharge occurring when a potential is sufficient to break down a dielectric has most interest to the electrical engineer, and to that only our attention will be directed.

On this subject there is a great mass of literature and while the results obtained by many investigators differ to quite an extent, yet valuable information can be had from a review of some of the methods adopted by earlier scientists.

The phenomenon of spark discharge is influenced materially by existing conditions, and also whether the dielectric is in a gaseous, liquid, or solid state. Dealing with this subject in gaseous media, Carr established the general law, viz., "that with a given potential difference, the field being uniform, the product of the pressure at which discharge occurred and the distance between the electrodes is constant." Here sufficient evidence was found to establish a minimum sparking potential (in air of about 350 volts) in gases and the investigations cover a wide range of spark gaps, and pressures varying from 0.1 to 100 *M.M.* mercury. The connection between the spark potential and the pressure of a gas for a given spark gap is, as the pressure of a gas diminishes the difference of potential required to produce discharge also diminishes until at a critical pressure the spark potential reaches a minimum value. Further, if the pressure is reduced below the critical pressure the potential difference rapidly increases. This minimum spark potential has been shown to vary with different gases.

The first spark passes through a gas with far more difficulty than those following, and an appreciable delay invariably occurs in the passing of the initial discharge. This delay is noticed more particularly in the neighborhood of the critical pressure, discharges being frequently obtained after intervals of fifteen or twenty minutes.

After discharge the potential required to maintain a current in a gas is much less than the sparking potential at pressures above the critical pressure, and vice versa. The fundamental laws of electricity no longer hold when a current of electricity is passing through a gas unless extremely small *E.M.F.'s* are used. The most noticeable feature of the discharge is that an increase in the distance between the electrodes increases the current for a constant potential difference. Nor does the conductivity follow Ohm's law but for small *E.M.F.'s* since an increase in *E.M.F.* does not produce a proportional increase in the current, the current increasing more slowly with the *E.M.F.* until it finally reaches a maximum or saturated value. The conductivity has been shown to vary directly as the square of the voltage, but prevailing conditions, such as the introduction of Roentgen rays, pressure, etc., are liable to have such an influence that this property may be increased or entirely removed.

If now, we consider very small sparking distances, there is at once a variety of opinions. Some investigators find that for small spark gaps such as from one to one hundred wave-lengths of sodium light, no evidence of a minimum sparking potential exists. Then on the other hand, Almy has shown that, in his work at such minute distances, the potentials previously recorded do not produce disruptive discharge but rather cause the electrodes to be brought into contact, and further proceeds to verify Carr's conclusion in reference to the existence of a minimum sparking potential.

The discharge in liquids is indeed very similar to that in gases and has been investigated chiefly by the larger manufacturing concerns, and obviously much interesting information has not been published. In most dielectrics the spark appears very bright, in oil it is of a greenish white color, while in alcohol it is red.

The character and application of the *E.M.F.* producing discharges also has its effects. While the data obtained by electric machines may be of no practical value to the electrical engineer, to the physicist the use of an alternating *E.M.F.* has its objections. Where alternating current transformers are used to step up the voltage, higher harmonics are invariably evident. The amplitude of the harmonics is increased by the effect of capacity which is in turn dependent upon that uncertain element, "time lag," in passing of discharges. Since the voltmeter registers the "square root of mean square" value, and even with the assistance of an oscillograph it is difficult to obtain the peak or break down voltage, unless sine wave forms are employed. Direct current admits of most accurate measurements of sparking potentials as well as producing a steady strain in the dielectric. Sufficient time should be allowed to elapse after a discharge to allow the dielectric to resume its normal state. Liquids, contrary to gases, usually require a higher voltage to produce a second discharge following closely after the first spark, and it is also a matter of common knowledge that oils have poorer insulating qualities for low than for high frequencies. Further, the more rapidly the potential is changed to produce discharge the less will be the potential required to spark across any given distance. The application of a definite potential suddenly will cause a spark to pass farther than if the potential were gradually built up. The sudden rises or surges in *E.M.F.* are frequently responsible in damaging electrical apparatus.

In the study of spark discharges we have seen that it is better to use constant *E.M.F.'s* which produce a steady strain in the dielectric due to the magnetic field. The effect of the field is more pronounced in gaseous media than in liquids and especially in gases at low pressure. The field distribution is greatest near the electrodes but it should tend to distribute the stresses as uniformly as possible to avoid partial break downs. The intensity may be increased by reducing the spark gap and shaping the electrodes.

The effect of moisture in a dielectric is no doubt to facilitate the passing of disruptive discharges. The great majority of failures occurring in high tension apparatus and even in all classes of electrical machinery is invariably chargeable to the existence of moisture in the insulation and in fact all modern manufacturing establishments are equipped with drying and vacuum ovens, etc., for the elimination of all moisture.

Similarly we might mention the effect of temperature. The allowable working temperatures of transformer oils seldom exceed 80° *C.*, although the disruptive strength of oils would appear to be little affected unless some change in the state of the dielectric were brought about. The temperature effects are more pronounced in liquid than in gaseous media, since in the latter the heat is more readily dissipated.

Finally, let us consider briefly the electrodes and their resulting effects . There is little or no objection to the use of parallel plate electrodes where the spark gaps are relatively large, since uniform fields and accurate distances are readily obtained. For small distances, however, this plan is not satisfactory. If discharge occurs between a point and a plane, it will be found that when the point is positively electrified the potential difference will be greater than if the point is negatively electrified and for comparative tests it would be necessary to maintain the point at one electrification. A similar effect occurs if the electrodes are of different sizes unless the discharge is maintained.

Again, the electric intensity upon small spheres is greater than on large ones and discharges will pass more readily. Hence it would appear the most satisfactory electrodes are medium spheres, necessarily hard and highly polished, to avoid easy disfigurement. In wireless telegraphy also has the subject of electrodes been considered. Here it has been observed that where a point and a disk are used the discharge is brighter than with two points. With a point and a sphere the visible properties become reduced, whereas with disks or flat surfaces there is usually a convective discharge around periphery and discharge shifts from one position to another. So that in practice to obtain the best results it is clear the terminals must offer no sharp edges or points, therefore spheres are the usual form.

The effect of material composing the electrodes seems to have no appreciable effect upon sparking potentials unless the gaps are small enough to cause the passage of minute particles of the metal.

ADDRESS—THE ENGINEER; HIS CHARACTER, TRAINING AND PERSONALITY.

WALTER FRANCIS, C.E.

Mr. President and Gentlemen—Fellow Students:

In order that we may get together let me tell you a little story I heard a short time ago regarding a newly married couple who were staying at a large hotel. The gaze of the curious annoyed them very much and in the dining-room the groom called a waiter to him, saying: "Here, fellow, is a dollar. The stupid staring of all those people is very annoying to myself and wife. We don't want everyone to know we are a bridal party. Just see if you can't get it stopped." The next day the groom again confided to the waiter that they were attracting more attention than ever. The waiter became very serious, expecting to be chided for not having earned that dollar, and he hastened to explain: "Well, boss, I doan know how dat is. I'se been 'splainin' to 'em dat you ain't married at all."

I might have started with a long face and said, "Let us smile." But we are not at the King Edward and it is the clerical sound of the expression that appeals strongly to me just now for I fear before I resume my seat that I shall have done those things I ought not to have done and left undone those things which I ought to have done. In any event I shall do my best.

On an occasion like the present, one is very apt to become reminiscent and I shall ask your indulgence for a moment while

I digress sufficiently to give you a comprehensive idea of what was here in the School of Practical Science in the late eighties in order that you may have a glimpse of the tremendous achievements of that man whom we all respect so highly, that man who stands out so prominently in scientific education, that man whose name will be emblazoned in the pages of the history of engineering education in Canada and indeed in America—John Galbraith. And when I shall refer to the three great features of an engineer's life—character, training and personality—do not forget that you have a model before you constantly while you are in this institution—a man whom we all revere—a man accessible on all occasions to the true student—a man whom it is a privilege to call a friend—our worthy Dean.

It is just twenty years this autumn since the speaker came to the School as a special student in architecture. In those days the wing of the old, red brick building was the "school." The front door faced the campus. There was no regular architectural course. At that time Robert A. Ross, the well known electrical engineer, who was the first regular student in mechanical engineering, took his lectures all by himself from the Principal in his private room. Then, as I presume now, the echo "Five o'clock, gentlemen," resounded through the halls in due time. Dr. Ellis and the Principal were the only two full professors and it was not hard to count the staff. The regular Indian file from lecture room to lecture room is still vividly before my mind. Every student—many of them well up in years—bore that strained expression which read plainly that he had undertaken tremendous responsibilities. Bald heads and full whiskers were not uncommon in the classes. In the comparatively short space of twenty years the old timer returns. The number of buildings, the large staff, the mechanical equipment, the hosts of students bewilder him and he feels lost. Building after building, passage after passage, door after door confronts him until he realizes that it is no wonder that it takes some fellows many years to get out of the place.

Fortunately the day is past when the public thinks of the engineer as a sort of glorified plumber. Engineering is rapidly taking its proper place in the front rank of the professions. The engineer of to-day has to be a broadminded man, skilled in the art of construction and able to meet men. The problems confronting him in adapting the great forces of nature to the use and convenience of man are the greatest in the world to-day. The great financial schemes for the most part depend directly on engineering and the engineer. Wipe out the railroads, the shipping, the ports, the mining and manufacturing appliances, electrical and mechanical devices and you restore a condition in which would revel the American Indian and the Eskimo. The clergyman deals in the future. The lawyer is expected to do the best he can for his client. The doctor buries his mistakes. The engineer erects monuments to his ability or lack of it. The structures he builds hold in safety the lives of thousands, and provide for the whole world those things which may be said to constitute its civilization.

It is a safe hypothesis that the engineer of to-day has received a technical training. There are some, of course, who cannot get it. In the past the privilege did not exist. Many of the greatest engineers of the world never saw the inside of a university. If they had done so no one can say what their accomplishments might have been. But the feature I wish to mention particularly is this—the trained man has an equipment which enables him to solve problems and overcome difficulties which none but the highest genius can otherwise surmount. The trained man with a proper appreciation of things is able to attack his problem and reach a solution in a fraction of the time occupied by one not so fortunately equipped. But do not mistake me. Engineers, like poets, are born, not made. No amount of technical education will enable one without the natural inclination to become an engineer worthy of the name. It is more than likely that the great majority of those whom I address have the true natural instincts of the engineer. My sincere wish is that you may all be eminently successful. But in a body so large there may be some a little out of place. It is remarkable to think of the small happenings, the trifling occurrences that influence us in life at times. Why some of you are not in arts or medicine you know best yourselves. If your choice has not been a happy one I trust you may be able to realize it before it is too late.

I see that the bulletin board has confined me to a subject—the influence of character, training and personality in the work of the engineer—and I must bow in submission. The effect of character, training and personality cannot be lightly passed over in connection with the work of an engineer. I trust you have all read Mr. Stern's most excellent address entitled "Advice to the Young Engineer," published some months ago in APPLIED SCIENCE. If you have not done so, procure the copy at once, and read carefully also the discussions that Mr. Stern's remarks evoked from leading engineers. Too much cannot be said on the subject. Let me take the main points in order—first, character; second, training; third, personality.

The first and most important element in the character of every man is honesty. "Great is truth and mighty above all things." If I were asked to describe in a word the science of engineering, I would say "truth." The words "the truth shall make you free," certainly apply to the engineer. When you know the truth of the materials you handle, the truth of the principles you apply in handling them, and you are true to yourself, then you have reached the proper position for an engineer. Don't deceive yourself. Don't try to make yourself believe something about which you have any doubts. Be clear. The engineer must be true to others as well as to himself. He deals with truth as far as it may be available. Keep your honor bright. The acknowledgement of an error or of some shortcoming does not affect your integrity. Above all things be honorable. The student who tries to make himself believe he understands when he does not is his own worst enemy.

In student life, freed from home restraint, there is possibly the tendency on the part of some toward dissipation. Against this let me warn you in the strongest terms. The student in his vigorous young manhood should be most careful in this regard and cultivate the proper spirit of manly self-control. His associations and associates should be of the highest character. He should form alliances with those societies which seek to benefit mankind. His friendships should be true and lasting and he should cultivate particularly the acquaintance of good men and good women. He should practise moderation in everything and not be given to any excess. With a character so developed, trained honestly and combined with a pleasing personality the young man is thoroughly equipped for life's battle.

The engineer receives his training in two schools — the university and the school of experience. Let us refer to the university life as education and apply to it Lord Kelvin's definition: "The first object of an education is to enable men to live; the second is to enable other men to live." Many persons in addressing you on these subjects would deal with the importance of trigonometry and higher mathematics. I would go farther back still and say the subjects of first importance are the three r's—readin', 'ritin' and 'rithmetic. These are the subjects the engineer uses most and consequently abuses most. Not one in a hundred can read well. Accountants can write the addend of many columns of figures before an engineer gets down the first column. The handwriting of many engineers would be put to shame by the characterless efforts in a schoolboy's copy-book. Too much importance cannot be placed on the necessity of being able to write a clear, legible hand denoting character.

As to the age of admission, I would advise nobody—I speak as a general rule, and of course there are exceptions—I would advise nobody to enter an engineering course before the age of 20 or 21. Get a general education, go and drive a grocery wagon, learn something of the rough corners of the world, get a little appreciation of things, and then—then you are in a better position to absorb the wonderful truths imparted so thoroughly within these walls and to appreciate their meaning and importance. The immature mind of the boy is quite unable to grasp the full importance of the lessons taught. Engineering lessons must not be done like school lessons. Forget all about your examinations. Imbibe the principles and the examinations will take care of themselves. Everything placed before you in the course is done by competent academicians after mature consideration. You yourselves are not yet in a position to judge of it. But whatever you do, absorb the principles. Let me hesitate for a moment to say that nothing short of loss of sensibility will ever knock $\frac{p}{y} = \frac{M}{I}$ out of my head, and I trust his assistants are following in the footsteps of their Master-mind who so thoroughly impregnated our being with "first principles."

As I said, everything is important. But somebody will doubtless expect to hear some subject mentioned specifically. Learn all about drawing. More graduates have obtained a start in life through their draftsmanship than in any other way. Give particular attention, too, to the adjustment of instruments and the elimination of errors in them.

Be attentive to your engineering society. Attend its meetings and take part in its discussions. Cultivate public speaking. Here let me throw a bouquet. Many of you were at that memorable gathering in Convocation Hall last January when the Canadian Society of Civil Engineers were the guests of our Society. You will recall the speeches delivered by the undergraduates on that occasion. It is my good fortune to be personally acquainted with the graduates of many institutions all over the world, and you would blush with pride were I to repeat to you the complimentary things said of your speakers at that gathering. In the Engineering Society you have opportunities you cannot get elsewhere.

It has been said that a man goes to the university to learn how to learn. One of the great sources of learning is reading, so I say, learn how to read. Read regularly the recognized engineering periodicals. Attain all the breadth and culture within your reach. Get out of the little sphere in which you have been reared. Remember that there are other peoples and nations, other viewpoints and systems. Don't be narrow-minded.

And don't be discouraged if you can't stand high in your class. The slow student is not necessarily a poor student. The students referred to frequently as the "best" often do not make the best engineers. Remember what I said a few minutes ago —engineers are born, not made. For the encouragement of those who may feel a little discouragement now and again because they seem unable to keep the pace, let me repeat—be sure of your general principles, build on the solid foundation of good character added to a properly developed personality, and success is yours. The mathematician, for example, may be a leader in classes, but he will find the cold, hard world far from being mathematical. I know of expert mathematicians who are of less real service than a good office boy in actual life.

Now when you graduate, be careful. You have done well. You have made a good start. Probably your hat feels very tight —but nobody else thinks so. You are only commencing to begin. The school of experience is not easy to matriculate into. The course for many is a hard one. None of us may say what the hand of Destiny has in store for us. We enter life. The race is harder for some than for others. The prizes are many but the handicaps are likewise many. Some do not start. Others get away at the first sound. A few fall by the way. As we go on the journey we gather information to enable us to run more easily and possibly more rapidly. The adverse winds are not felt or encountered by all. For the great majority there are prizes.

In the school of experience you learn how to appreciate the general principles and how to make proper assumptions in order to use them. You learn that at times a carpenter's line and square have their place and at times they are more expeditious to use than a transit. You learn—if you are wise—how to do everything that concerns your chosen line. From every person with whom you come in contact you learn. The Italian with his rock pick can show you how to strike a blow that will loosen twice as much rock as you can. Every mechanic can show you details that you never dreamed of. Every hardware clerk can name a score of standard engineering articles that you do not even know the commercial name of. From the foreman you will learn how to handle men. From the contractor you will see how to handle work. Everywhere you go and turn you can acquire information. Don't consider anything too menial. The engineer who is able to rise to the emergency is the man who commands respect and who will be followed by all. Know how to tie ropes, drive rivets, make the injector work, fire a boiler, tap nuts, wipe joints, handle a trowel, handle blasting materials, and the thousand and one things that have to be done on works. And just here let me give a word of warning to the young man who thinks it of more importance on works to be ornamental than useful. Hesitate for a moment—probably you are the only one who ever even dreamt of the ornamental aspect, notwithstanding your high collar and fine clothes.

Be careful to acquire a complete experience in the details of office work. Learn to use a typewriter. Find out all the office boy does and be sure you can do those things yourself. You would be surprised to learn how few engineers can dictate a letter, typewrite it, copy it and mail it in due form. But these things have to be done personally at times, so learn how.

Learn to make proper records, notes and sketches. Remember, you may not be on hand to explain something later.

Get a year's experience in a bridge company's office, for there you will learn what is really only high-class clerical work —bridge drawings for shop work. Nothing else gives so good an insight into the art of commercial draftsmanship.

Learn how to take photographs. You can pay for the developing and so forth, but the taking is the important feature. Only the engineer knows what to take and when to take it.

Do your specializing after you leave school—you may begin to think about preparing to specialize when you enter the school of experience.

Above all, learn to accomplish things. In these day's they want the man who can do things. Don't be content with ordering. Get busy. Accomplish a result. Carry the message to Garcia.

Cultivate the habit of being ready to work. Keep on your person all the little odds and ends you need from moment to moment.

Be sure you're right, then go ahead.

Just to relieve the monotony let me tell you another story. It tells you what monotony really is at times. If you wish another excuse for my telling it I may say that it was told at a banquet in New York where probably the largest number of English-speaking engineers that ever assembled were gathered around the festive board at Delmonico's. I well remember one of the leading speakers describe a lawyer addressing the jury in defence of his client who was on trial for being too much married. Striking an attitude, the legal man said: "Gentlemen of the jury, when a man has many wives we call it polygamy. If he has two wives the law terms it bigamy. But if he has only one wife that's monotony."

Now as to personality—who may define it? I cannot. There are many things we know about it, but who can say exactly all the reasons why some attract us while other persons repel?

Probably personality has as much to do with obtaining employment as any other single feature. The Dean stated in one of his addresses that an engineer should be 100 per cent. engineer and 100 per cent. man. The statement is mathematically correct. Be manly. Be congenial. Cultivate proper friendships. The friendships which many engineers prize most are those made when they began life and earned their position through integrity, ability and manliness. Don't be a worrier—nobody cares to have him around.

The personality is very clearly shown in letters of application for employment, so be careful how you write them. It is still more clearly shown in applying personally for work.

Don't be eccentric, for none but a genius can afford to be so.

Co-operate with those with whom you are associated. Don't antagonize.

Before I resume my chair let me pass on a few general words of advice. The question of success is one of life's problems and as such can be discussed *ad infinitum*. It cannot be denied that there is a tide in the affairs of man which if taken at the flood leads on to fortune. I trust you may appreciate opportunity when she knocks at your door.

Cultivate a horror of fossilizing. When you find you have a snap it's time for you to make a move. Any fellow can get along when things go straight but it takes a good man to make them go under difficult conditions.

In handling your work, if you wish to make speed lend a hand with the menial work. A survey can frequently be done quickest with the leading man driving stakes. More time is lost on any work doing the trifling things than the apparently more important ones.

While you're working forget the clock. If any of the members of your body assert themselves there's something wrong. And there's something wrong when you are worrying about what time it is. When your employment is congenial and everything is going well you forget there is such a thing as time. While speaking of this let me strongly urge all young men to be careful about punctuality. Keep your appointments to the minute and expect everyone else to do the same. The young men on construction works should be there from whistle to whistle.

Again I say, be broadminded and liberal in your views. In late life you will be placed in somewhat judicial positions. Remember, there are two sides to every question.

Dr. J. A. L. Waddell in one of his addresses refers to an engineer thus: "He must be intensely practical yet perfectly technical; minutely accurate yet properly approximate; firm in his beliefs, yet open to conviction, knowing where firmness stops and stubbornness begins; courteous and helpful to his contractors, yet never conniving with them to the slightest degree; dignified yet affable; and in short, a thorough gentleman, yet never ashamed to do any work, however apparently menial, provided that it belongs properly to the engineering profession." Let us look at that quotation again.

In conclusion let me repeat—be honest, be studious, be a man. Ally yourselves with those organizations which make for the benefit of mankind, and keep out of politics.

The keynote of the whole is, be natural.

PETROLEUMS AND COALS COMPARED IN THEIR NATURE, MODE OF OCCURRENCE AND ORIGIN.*

EUGENE COSTE, E.M.

There is found in nature a great variety of compounds of carbon, not only in the sedimentary strata of all ages, but also in crystalline rocks, in igneous and volcanic rocks, in seams and veins through all these, and even in meteorites.

All these carbon-compounds have been assigned by many geologists to the one and the same origin, namely:—an organic origin, from the decomposition or distillation of either animal or vegetable organic matter entombed in the strata, and they have all been grouped and classed in the one and the same series of compounds of carbon.

This organic origin cannot of course hold good for the natural carbon-compounds found in crystalline rocks, in igneous and volcanic rocks, in volcanic gaseous emanations, in metallic seams and veins where they are intimately associated with such minerals as quicksilver for instance, and also when they are found in meteorites. It has, therefore, always seemed to me that this idea of only one natural series of compounds of carbon with an organic origin, is so clearly at variance with so many well known geological facts and physcial laws that I cannot cease to wonder how it is possibe for such a huge error to have taken the firm root it has in the science of geology. In two papers which I read before the Canadian Mining Institute, one nine years ago ([1]) and one six years ago ([2]), and in another paper which I read in 1904 before the American Institute of Mining Engineers ([3]), and before the Franklin Institute ([4]), I entered my strong protest against this fallacy. I pointed out in these papers the solfataric volcanic origin of the natural hydrocarbons or petroleums. Other geologists have also long ago given proofs of the inorganic origin of petroleums, especially Berthelot, Mendeléeff, Eli de Beaumont, De Lapparent, and a number of other writers mostly French and Russian.

But it evidently takes a long time to establish definitely even simple and palpable truths in science, as may be judged from some of the recent literature on the subject ([5]) in which the derivation of the natural hydrocarbons from organic matter is either again admitted without discussion or again sought to be proved. It appears, therefore, necessary that some of the facts in the case be once more presented, and I have adopted in this paper the comparative form between coals and petroleums, in the hope that it will bring out more forcibly and more clearly how entirely and absolutely different some of the natural carbon-compounds are to others in their nature, their mode of occurrence and their origin; and in the further hope that it will demonstrate that there are really two series of natural compounds of carbon, namely the Organic or the Coal Series, or Coals, and the Volcanic, or Petroleum Series or Petroleums.

---

*Address before Mining Section Engineering Society, October, 1909.

1. Journ. Can. Min. Inst., Vol. III, 1900, pp. 68—89
2. Journ. Can. Min. Inst., Vol. VI, 1903, pp. 73—128
3. Trans. Am. Inst. Min. Eng., Vol.XXXV, pp. 288—297.
4. Journ. Franklin Institute, Philadelphia, 1904.
5. The Data of Geochemistry, Bulletin No. 330, U. S. Geol. Survey, pp. 619—641.
   See also U. S. Geol. Surv. Bull. No. 250, 265, 282, 285, 300, 309, 317, 318, and others.

Nature.

Coal Series.—The coal series includes the natural carbon-compounds grading into one another from vegetation into peat, lignite, soft coal, semi-anthracite and anthracite.

One hydrocarbon, namely marsh gas or methane, is known to form, during the natural decomposition of vegetation, into coals; this is the only hydrocarbon thus formed. Many other gaseous or liquid hydrocarbons may be produced by the destructive distillation of carbonaceous matter or of coals, but these have nothing to do with the carbon-compounds formed in nature by the normal geological processes, as the destructive distillation of the sedimentary strata and of its carbonizing vegetation is not a normal geological process and never took place. This is conclusively proved by all the undistilled ignite and coal beds of the sedimentary strata all over the world and by the want of coke beds in these strata.

Petroleum Series.—The petroleum series includes all the natural hydrocarbons with the exception of the marsh gas above mentioned. These petroleums grade from natural gas into fluid crude oil or petroleum proper, into semi-fluid maltha and into viscous or solid bitumen or asphalt in their many varieties, of which such minerals as grahamite, gilsonite, elaterite, napalite, ozokerite, albertite, anthraxolite, are only a few. As the end products of the petroleum series there are good reasons, as we will see, to include both graphite and diamond, whose deposits prove that they also have had a similar inorganic origin.

A good definition of the nature of petroleum is the one of Mabery (6) as follows: "petroleum, from whatever source, is one and the same substance, capable of a simple definition:—a mixture in variable proportion of a few series of hydrocarbons, the product of any particular field differing from that of any other field only in the proportion of these series and the members of the series."

Mode of Occurrence.

Coals.—With regard to the mode of occurrence of the members of the coal series it is only necessary for the purpose of this paper to note that they are always found in regular beds of the sedimentary strata spreading uniformly far and wide, often over hundreds and even thousands of square miles.

There is only one point which I think pertinent to make here with regard to the mode of occurrence of the coals, and that

---

6. Joun. Am. Ch. Soc., 1906, XXVIII p. 417.

is that no coal beds are found below the Carboniferous period. A small amount of coal or carbonaceous matter is, however, found in some of the Devonian shales, but this never passes into pure coal beds and fewer and fewer of these carbonaceous shales are found in the Silurian and Cambrian. The science of geology has always interpreted and explained this fact—that so little coal is found below the Carboniferous—on the understanding that before Carboniferous time the conditions for the existence of considerable growth of vegetable matter were unfavorable and it is a geological heresy to speak of or to believe in coal beds existing in formations lower than the Carboniferous; geology teaches us that they cannot and do not exist there. How is it then that there are so many large deposits of petroleums below the Carboniferous? It could not be because there was so little vegetable or other organic matter entombed in these early strata, unless their origin is not in any way organic.

Petroleums.—If the mode of occurrence of coals is well understood, the mode of occurrence of petroleums certainly is not, and hence the great misunderstanding by so many concerning the origin of the later. Some geologists have passed such, to them, unwelcome cases over with the remark that the petroleums in the igneous or volcanic rocks were no doubt due to the distillation of the bituminous shales cut through by the intrusions; but how can a hot rock distill or drive away a vapor into itself? In one of my previous papers ([7]) on this subject before this Institute I cited a good many instances of petroleums in volcanic emanations or in igneous or volcanic rocks, and for full particulars of these reference may be made to this publication, but I will recapitulate here what these instances prove beyond all doubt:

1st. The occurrence of graphite in igneous gneisses, granites, gabbros, pegmatite dykes and in a quartz-porphyry dyke.

2nd. The occurrences of hydrocarbons in the gaseous inclusions of the crystals of igneous rocks.

3rd. The occurrence of petroleums (liquid, semi-liquid and solid) in greenstone traps, in basalts, in trachytes, in dolorites and other volcanic rocks.

4th. The occurrence of diamond and gaseous hydrocarbons in volcanic necks and pipes.

5th. The occurrence of gaseous and liquid petroleums in the volcanic emanations of to-day.

6th. The occurrence of petroleum in freshly ejected scoriae from the volcano Vesuvius.

In confirmation of the above a specially interesting proof of the occurrence of petroleums in crystalline rocks, in volcanic or igneous rocks or in close connection with these, and in metalliferous veins, may be cited:—

The occurrence of oil around volcanic necks, Mexico:—

---

7. Journ, Can Min. Inst. Vol. VI, 1903, pp. 73—128.

In the State of Tamaulipas, Mexico, in the Gulf-Coast lands, the oil deposits are found around vertical borings, chimneys or pipes drilled upward through undisturbed and almost horizontal shales by volcanic action during the Pliocene and perhaps Post-Pliocene times and forming small isolated cones ranging from a few feet to four or five hundred feet in height. These cones of volcanic origin spread over the coastal peneplain and consist either of solid basaltic lava or of basaltic tufa. At the base of these cones, or in their neighborhood, are to be found the greater number and more important seepages of oil. The Mexican Petroleum Company, at Ebano, near Tampico, have obtained their more productive wells at the base of the tufacious cones, such as the Cerro de la Pez, where from but very few wells around this hill they have secured a daily output of 6,000 barrels. In the more highly productive wells of this company the heavy oil, abundantly charged with gas, carries a sandy material consisting of small sharp pieces of shale, fine lapilli, and volcanic sand. The conditions above described as to the occurrence of oil prevail in an extensive zone of the Gulf-Coast lands and extend further south in Mexico to the northern half of the State of Vera-Cruz.

In the sedimentary strata of all ages some of the sediments, principally sandstones, conglomerates, limestones and sandy shales are occasionally quite porous rocks, and therefore may and do form catch basins, tanks or reservoirs for gaseous or liquid petroleums forcing their way under strong pressure through the fractures, fissures, seams and joints of the strata. These reservoirs when thus filled constitute the important petroleum deposits, the commercial oil—and natural gas-fields. They are found indiscriminately in hundreds and hundreds of horizons in the strata of all ages, from the oldest paleozoic to the alluvial gravels and sands of the Quaternary. The natural gas or gaseous petroleum in these reservoirs is always found to have a heavy pressure, sometimes as high as 1,500 pounds to the square inch and in this connection the most important fact to be noted is that this pressure increases in each particular field with the depth of the porous reservoir or "sand" containing the petroleums, indicating that its source is from below.

Far from forming, like the coals, uniform beds, spreading out uninterruptedly in every direction over wide regions, the petroleum reservoirs on the contrary are always found to form comparatively small, local, accidental and irregular pockets, pools or fields. In these pools or fields themselves extreme irregularity is often the characteristic of the reservoirs; patches and strips of barren and productive territory being intermixed in most intricate manners, leading often to productive wells being surrounded by dry holes, and vice versa. In many of these fields the oil and gas are obtained in a number of different sands or reservoirs, some of which are hundreds and thousands of feet lower than the upper one and again in that respect in some of the fields there is great irregularity as to what depth the producing reservoir will be found; in neighboring wells the oil or gas may be tapped at entirely different depths. To any keen observer the above features at once demonstrate absolutely that the petroleums in all of their reservoirs are wanderers, not in their original home, and that all their deposits are deposits of secondary impregnation.

Origin.

The opposite chemical nature of the members of the two series of natural carbon-compounds, namely, oxidized complex carbon-compounds for the coals and a mixture of reducing hydrocarbons for the petroleums, gives us the first hint of the surface or external origin of the coals and of the internal origin of the petroleums. Beneath the earth's surface, as is well known, there is a deficit of oxygen, and hence we find none in the natural hydrocarbons from the interior, except in the solid varieties which are the oxygenated and sulphureted residues of the other petroleums in places where they came near enough to the surface. The coals on the contrary obtained their oxygen from the atmosphere at first in their original state of vegetation, and have retained part of it during the carbonizing process to which they have been subjected.

Coal Series.—The origin of the members of the coal series from the natural decomposition of vegetable matter, either in place or drifted, is abundantly proven, and is now generally acknowledged and admitted among geologists.

Petroleum Series.—It is, however, very different in the case of the petroleums, the origin of which is still admitted by many, as a matter of fact requiring no demonstration, to be due to some unseen and unexplained decomposition of organic matter. Other geologists have discussed the subject at length and have tried to prove the organic origin of the petroleums, but not one has ever been able to point out to a single case where a petroleum production process coeval with the kingdoms of life could be witnessed in nature to-day. Some other geologists are discouraged and proclaim the origin of petroleums as a profound mystery not yet solved by science.

As I have long contended, I, for one, cannot understand how it is that the solfataric volcanic origin of the petroleums should be considered as any more doubtful and less proven than is the organic origin of the coals. It seems to me that the geological facts proving the one are just as clearly established scientifically to-day as are the facts proving the other. They are simple facts, the A. B. C., so to say, of geology, and yet strange to say they are every day ignored and set aside.

The origin of the petroleums is not organic; that it is volcanic is absolutely proven by:—

1st. The fact that volcanic emanations of hydrocarbons are the only natural geological process of petroleum production of to-day, abundantly verified and witnessed in actual operation in volcanic eruptions and phenomena all over the world.

2nd. By the presence of petroleums in volcanic rocks, igneous rocks, metalliferous veins and meteorites.

3rd. By the rock pressure of the natural gas in the petroleum deposits. This pressure always increases with depth in each field; it has been well proven that it is not an artesian water pressure from above, and it cannot be explained in any other way than as a remnant or spark of the volcanic energy forcing the petroleums through the crystalline rocks and all the sedimentary strata from below.

4th. By the products associated with the petroleums in their reservoirs, principally salt, sulphur, hydrogen sulphide, gypsum, calcite, dolomite and silica, which are also the products associated with hydrocarbons in the volcanic emanations of to-day. This association is the unmistakable solfataric volcanic seal which I pointed out before ([8]).

5th. By the hot oils, gases and waters in some of the more recently formed petroleum fields.

6th. By the fact that the petroleum deposits are located along the faulted and fissured zones of the crust of the earth, parallel to the great tectonic, orogenic and volcanic dislocations and in "petroliferous provinces" analogous to the metallogenetic provinces of DeLaunay, Lindgren, Spurr and other writers. These petroleum deposits could not be inseparably and intimately connected with the tectonic structure of each particular region unless their source was as deep seated as the forces which have caused these profound dislocations of the crust.

7th. By the fact that petroleums are never indigenous to the strata in which they are found, and are clearly secondary products impregnating porous rocks of all ages. In all fields there is always a lower horizon in which the petroleum is found, until finally the crystalline rocks are reached, and they are even found in these. This adventitious nature of the petroleum deposits is further illustrated by the deposits of solid petroleums which cut through all rocks in veins exactly similar to mineral veins.

8th. By the fact that petroleums are found in such abundance in certain small localities, while neighboring localities are found entirely barren; this forces one to the conclusion that they must originate from the volcanic tank below which is the only one adequate to furnish these enormous quantities to narrow long belts or to small isolated spots, such for instance as the one hundred acres of the Spindletop Mound, near Beaumont, Texas, which has already produced about 38 million barrels of oil; such as the one billion of barrels produced from a small area in the famous oil-field of the volcanic peninsula of Apcheron, near Bakou, Russia; and such as the millions of barrels produced in many other fields from very narrow long belts while areas

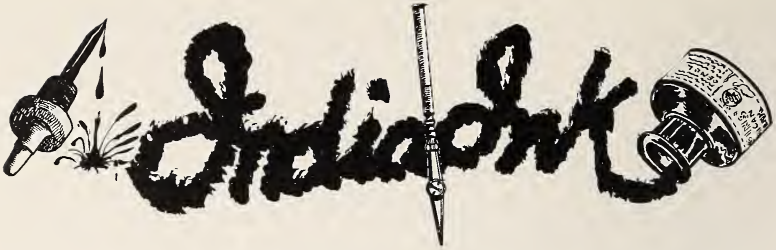
---

8. Trans. Am. Inst. Min., Eng., Vol XXXV pp. 290—294.

many scores of times larger next to the producing strips are barren; this cannot be held to be an accumulation in the producing fields from vast surrounding areas of sediments, as if this was supposed one could not explain why the petroleums did not escape to the surface instead of travelling so far laterally.

9th. By the fact that the sedimentary strata of the oil-fields are so highly impervious that the volcanic fracturing and fissuring and the volcanic force of the natural gas alone can explain how so many small porous receptacles at different horizons between these impervious strata, have been filled with petroleums, salt and sulphur waters, and how these small detached petroleum reservoirs are found to-day under a gas pressure which increases with depth in each district but is nevertheless a stored energy which will dissipate gradually in the utilization of the oil-field, the volcanic energy which brought it there at one time being now dead and inactive.

Before concluding permit me to insist on the fact that the recognition of the solfataric volcanic origin of the petroleums not only removes every difficulty in the way of a full comprehension of all the chemical and geological facts established to-day with regard to the nature and mode of occurrence of these products, but it fully harmonizes also with the physical laws governing the circulation of gases and liquids through great thicknesses of very impervious strata before being able to reach to and accumulate in a few small separated receptacles in the midst of these. The volcanic origin of the petroleums forms, therefore, a complete chain of evidence, with none of the links weak or missing. The very reverse is the case, as I have shown above, when one attempts to explain the origin of the petroleums by means of organic sources;—in doing so, well known chemical and geological facts are set aside and ignored and physical laws are distorted and abused. The geologists who still hold these views should seriously reflect on this, and I am confident that if they do they will soon abandon and relegate to the past the old unsupported notion of the derivation of petroleums from organisms and that they will come to the conclusion that this idea is now unworthy of the progress made by the geological science of to-day.



A RETROSPECTION.

BY C. M. CANNIFF.

(Illustrations by W. Van R. Reynolds).

Mr. E. C. Easy, C. E., inserts as foreword to his monograph this well-known quotation from Pickwick Papers: "Tears never yet wound up a clock, or worked a steam ingen." Then, and thus, he goes on:

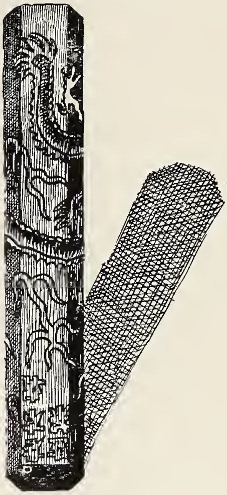
In amiable response—for I'm nothing if not of the anything-for-an-Easy-life sort of chap—in a true, free-grant response to a request of the Secretary of the Association for a paper, "even," he pleaded, "even if it be only about India Ink," I sat down with my "comfiest" pipe and thought long and earnestly. Two subjects readily suggested themselves and were hard to down: "The Reign of the Parallel Ruler," and "The Yonge Street Bridge Disaster, with Special Reference to the 'Long Lost Chord'," but as I realized that the Secretary best knew the Association's requirements—had given me, as it were, an India inkling of the same—I duly conveyed to him a few random reminiscences upon the ink our fathers wore out. Surely, my masters, it is eligible for an elegy.

In a familiar, eat-out-of-your-hand manner, conversational-like, so as to make due clarity of a subject somewhat obscure, I proceeded as follows:—

You will bear in mind the India ink I refer to—the sort, don't you know, in vogue before the genesis of *coli communi*, before we had the autocrat of the autocart—in the days historic, when we took a week with a half-hour plan. So I began blithely.

Not having what you might call a fair start, just here I swung off on a three-throw switch or something, and hazarded a remark or two about these plans of yore. Happen with the best of writers, what? One whole day usually went to make a survey for a border that would close, and a couple more for a title.

Nowadays, we make the most commodious border as single-minded and undemonstrative as four knitting needles laid one to the next rectangularly, with never a frothy bow-knot or sign of indecision about the corners; but the old idea was to rhapsodize about and fret them in a whirling eddy of random fuss and fancy. And those prideful, richly dowered titles, bedecked as any strutting peacock, with their reverse curves, and fantastic, festive, festoons; curlicues, cavorting roundabout as lightly as Raphael's pictured children; they were very eye-feasts, dithyrhambs in sinuous black and white. In their French curve elaboration, for pure flambuoyant beauty they ran a close second to a moving picture of a choicely romantic water-fall, or the trail of a champion skater on keen ice doing what is technically called "the grapevine, with variations." The delineator had to draw the line somewhere, of course, but managed to get it pretty promiscuous and bountiful. And if the mantling title did not vaingloriously dominate the plan, the "North Point" did. It was always kicking up high jinks, always posing. In brief, your North Point, instead of being the outspoken, lean and grim thing of to-day, was nothing short of a ballad, your border was a roundelay and your title made a noise like a cross between a grand opera, a warwhoop, and an Aurora Borealis.



But to take to the main line again. The archaic India ink came in long sticks, sort of aristocratic electric light carbons; scale of hardness, 10.99; as to transverse cross-section generally circular, ofttimes square, not infrequently rectangular; or, it might be, glorying in octagonal ornamentality. The vendor handed it over to you smooth, lustrous, embellished with curious cuneiform characters in shiniest gold, or else something horrific in zoological still-life. It was redolent of camphor or vanilla or some other scent of Araby—perhaps elsewhere—also, if you recall, seemed every whit good enough to eat. It yanked one back to the words of Macaulay when he mentions inhaling—no, not the abhorrently vile cigarette, but—

> "the balmy smells of nard and cassia which the musky
> "wings of the zephyr scatter through the cedared
> "alleys of the Hesperides."

You paid good money for it and took it home and injected a modicum of it into your pen.

But the preliminary manipulation. By the welkin and all its planets! The game was "Everyone his own blacksmith." 'Twas fraught with woe exceeding and tribulation. No, you did not go at it with an Indian file — it was a case of circular abrasion by the wet process, for like some mining stocks it was soluble in water. Pampered laborers in the technical vineyard as you are—vain voluptuaries of to-day, satiated sybarites! all you know is how to embathe your pen in some kind of hand-me-down, buy-no-other solution, warranted by the manufacturers of even flow—the which accompanied by its goose-quill stopper, and wrapped in its dainty and gratuitous serviette, its dip cork and clean rag. When you go a-lettering your nerves are steady and your hand as light as the angel shapes that bless an infant's dream. You're a spoilt lot; you've been spared the stick and brought up on the bottle. To me is it given to comprehend why Keats wrote,

"O aching time! O moments big as years!"

I understand; he wrote with the wrought ink of the dark ages. your hand is light. You're a spoilt lot; you've been spared the stick and brought up on the bottle. To me it is given to comprehend why Keats wrote,
But I fail to fatho mwhy they called it India ink; it came from China. I think it must have been the original Chinese puzzle we hear about. Probably the Li Hi's were ashamed of their Chink ink. Come to ponder it over, Alphonso holds no impregnable patent on the aesthetic yet companionable, even diverting onion labelled "Spanish." These generic terms, like proper names, are often difficult to account for. Not to be egotistical, they call me "Easy," for instance—"which," as a deceased scientific writer of some note has said, "which is absurd."

You call to mind, don't you, you of the older school (as I said before), ere wireless telegraphy—in the days when engineers recked little and cared less about reinforced concrete, and did not give a hoot whether their neutral axis was situate, lying or being in the floor plate above, in the beam beneath, or in the footing under the earth—you call to mind, don't you, the "demnition grind" in those flat saucers? Bethink yourself of the crick you used to get in the neck if you had a tracing to make in a hurry, and arrived at the office late, but found your nigrescent fluidity evaporated to a black current jelly consistency, and when (stercoraceous oxgall and slimy soap unavailing) it was up to you to sail in, seize that little imp of darkness and slush round for a fresh brew?

It reminded you of the sign that a friend of ours who was away behind in his work put on his door: "Surveys and Plans made while you wait." Funny, wasn't it, how every table you tried was shaky, and you were fated to get your incubator (shall I call it) on a high spot, provocative of a grumbling noise like a loose dumb-bell in a barrel dragging anchor in a down-grade tunnel. Has your memory lapsed concerning that "roughy" spot that you tried—mistakenly—to strike because it seemed like something doing. You learned to do two things at once, grind ink and grind teeth.

You would start off, patiently, pensively, with nice clean water in a scrupulously cleansed side-dish, and rub and rub (round, round and rub), sometimes whistling below your breath like the grooms do when they wield the curry comb—then grunt softly past the dirty clean water, or ten cent sugar period (round, round and rub), through the creole, or fine cut, or mud-pie stage (round, round and rub), past the sad-colored black-strap semaphore (rub and rub and rub), until at length after twenty minutes or so your product looked as Ethiopic as a burnt cork in the inside of a blind cow wallowing in a pile of soot during a heavy thunderstorm.

Pshaw! a trial trip with a drawing pen produced only a dim grey line. No, more yet, keep at it! You were in a bad case. You wondered if stove polish—anything else—would work. Away you went till your head swam. Talk about radius of gyration, talk about the mulberry bush (round, round, round—rub, rub, rub). You had to hang on like a pup to a root. With blinkers goggled and brain reeling, you considered the chipmunk in his treadmill, going and going and arriving nowhere. "Grinding poverty" (pish, pish—tush, tush)—here was a very wealth of it.

The very devil was in that ebon shaft of hard-boiled ink of the middle ages, with its undecipherable cabalistic legend in gilt. It was bewitched, it was fey.

I can even yet see the specks and motes and hairs and other aerial debris that gravitated to the saucer. It took to whiskers. This old-time blacklead was as the fabled course of true love—it ne'er did run smooth and probably not of it written, "dark as midnight was the flow."

Then the oxgall pot would be seized—that epitome, that concentrated essence of odorous abomination—and you would surcharge your refractory dusky dye with an adult's dose of the contaminated run-easy.

You said in your heart. "All Gaul is divided into three parts, each smellier than the rest."

Next, the rubbing dry to a polish of your wet stick; if no rag were handy, the office towel suffered, or maybe the furring of the lowest portion of your pant leg. This was to prevent your stick cracking, also granulation of its nether latitudes. If cracks came, the only remedy lay in a surgical operation ending in a bandage of glued tracing cloth. If granulation set in, the little hard pellets had to be disintegrated with a knife.

Is it brought back to your memory how when you eventually achieved a choice deep vessel of jet-hued fluidity, you would attempt to prevent evaporation by wetting the rim and carefully pressing the cover tight? Many's the time and oft when you removed the lid you absent-mindedly laid it on your well-stretched drawing, projecting thereby a tolerably accurate embossed circle like unto the ground plan of a standpipe or a silo. When your toil was over, your cuffs were dishclouts, your vest was smeared, collar spotted, nose smudged, and altogether you were a realistic echo of somebody in a bad temper, and about as useful for a time in your chosen profession as an aneroid with appendicitis.

How a pig-tailed Oriental mixes his ink and keeps clean, search me! Small wonder they run to laundries—and opium. Pardon me for a temporary surrender to the seething within of the divine afflatus, but—

There was an idiosyncrasy about India ink,
'Twas best to be ground in an odious sink.

However, I want merely to explain how our office in those days got "woke up" and exchanged the tyranny of the old line India ink stick for the solace of the bottle, how it adopted the "Higher Inkism." It happened, of course, in the big draughting room. How well I remember it. First me; I was excessively busy, having got my level book all messed up through want of a little foresight; then, there was Mr. Brown, engaged on a colored sketch that no artist could paint; lastly, the chief—but more of these later.

The usual expensive Brussels carpet covered the floor; the familiar mottos and such like adorned the walls. Everything bound in Russia leather, the library made a brave showing with its technical reference books—"The Complete Angler," "The Hundred Best Receipts for Fly Oil," and the rest. Over the door was "God Bless our Home when Daddy's in the Bush."

The chief was Irish, a Dublin C. E., as I said, married. nine children; used to advise his pupils not to marry if they wanted to be successful; if they did, they became so much matched lumber. He ate Higher Mathematics like a sword swallower. I remember when I first came, and tried to be sociable. It was an off day, and he was calmly discussing his lunch, poring over a chapter of Quaternions, and licking his lips — over which, I know not. I ventured a suggestion that his page of equations looked like blank verse with the colic.

"Young man," responded the chief, gravely, "Quaternions are the poethry av mathematics: for universalithy, that atthribute of your Homer, and Dante and Shakespeare—is the very essential oil of Quathernions." I succumbed.

In common with others of the old school, upon hearing first of it, the chief was quick to damn hand-me-down ink as the "devil's frippery and seduction."

"That botthled matharial can't bey anny good," he declared; "I av used rubbed ink frish-made daily for forthy-five year."

Here the assistant looked up from his labor of emptying half a barrel of riotous blazonry atop of a title, and he chipped in and still further desecrated the accustomed environment of grace, mercy and peace. My particular aversion — was this assistant, super-supercilious, so self-sufficient. I used to wonder if there was not something I could put in his coffee and cure him secretly at home. He was tall and had an ingrowing voice cast from Cockney patterns. A pet affection was a blue-flowered waistcoat with whole battalions of large thirty-two candle-power buttons. He wore a glass in his eye, and more rings on his fingers than Saturn—also spats. I've known him cross-section a doleful dump of street cleanings in tan shoes and lavender spats. He revelled in Troy weight machinery about his necktie. To hear him talk you would have thought him possessed of all the winnowed and garnered engineering wisdom of the ages, whereas in truth he had only built a couple of pigeon-hole dams and dabbled in a few other technical trivialities.

Invariably Mr. Brown cast more disparagement upon me and my brand of inkcraft than the chief himself. If, perchance, I was being criticized, he would stand and grin through that ridiculous monocle of his, with an intolerable expression of amused interest. Now, having decided that it was nobler in a man to carry a transit over his shoulder than a shovel, and with the Second Year A. S. germ in my system, can you doubt that, having accidentally come to know and bless the name of Stiggin's Ink, the jendulum of my ambition to grind the heathen article had about reached the limit of its arc?

"But you have never used Stiggin's Ink," I expostulated, pursuing an argument that became almost a scene.

"Stiggin's! Oh, I say!" echoed the assistant in his accustomed tone of mockery, his aristocratic nose tip-tilted in scorn, "a vain thing fondly invented. Strikes me, the trouble with you young 'uns at the School is that you think you know it all. My word! you rub up ink like a half-breed cook brews coffee—it's either too bally thick, or too bally thin, or it's chock full o' grounds. Why, blame me, it's grind my own jolly well decent stuff for a plan. Look at this lettering now, I say, black as your boot—that's the way to have ink, ain't it, chief? That's what you call ink." And he purred along, and me crestfallen, and the chief commending. "No, siree," continued Mr. Brown, "none of that stuff for me. At the Registry Office they siy it jolly well fides out, and then where are their bloomin' records?"

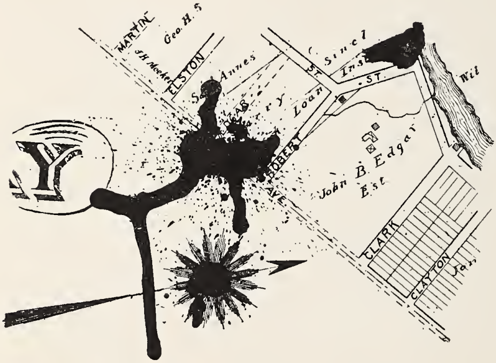
"Yes, that's the kind of thing," after examination, commented the chief; then with some asperity, "Be the powers. Aisy, you railly ought to pay hade to Mr. Brown. I niver like your ink, someway. Watch how he does it next toime. Rimimber the name of ye, Aisy, and 'Aisy does it' ye know. 'Nothing should be done in haste 'cipt catching fleas'—that's an ould proverb."

Mr. Brown gave an upward shear to one side of his circular optic glazing, it shot downwards, and he guffawed hugely. "Right, right-o, chief," said he, when his paroxysm had moderated to the old familiar smile. I gritted my teeth in silence. Mr. Brown slowly screwed his double sash in place, and resumed his drawing pen with. "Yes, Easy, you've a brisk lot to learn yet," the while a sardonic, facial expression as though some great sorrow had come to him.

Right there I noticed something peculiar in the assistant's movements—caught his eye momentarily—could I be right? With that transient gleam from the obtrusive monocle did there dart a weeny, little isolated arrow of menace? I had either to fight or get licked lying down.

I finished my task and convoyed my fresh saucer of ink over to the chief, who, by the way, was impatiently waiting to complete a sketch which had to catch the noon mail. Whatever happened, the dish slipped through his fingers and landed skew-"g"* on the floor. The language he employed towards me did not fall exactly as the grateful dew upon the green and tender herb of the field. However, talking of super-heated language, I care not who does the swearing of a country, if I build its dams.

"How in the 49th parallel d' ye think Oi'm to finish this now?" he queried, catching his breath. For a brief space the silence was that oppressive one could stick thumtacks in it.



Even a worm will turn. "Maybe Mr. Brown'll lend you some of his," insinuated I, with never a smile, valorously challenging fame and glory. "There in that top drawer," I nodded to the assistant, "covered over with your newspaper." The eyeglass took a sudden drop, and so did Brown, Esq.

The chief was in a hurry, and there was nothing for it. I *had* Sir Assistant. He was harried and undone. "Eh, what? Confound it! Go, blime me!" Just like that. "It's a bottle of Stiggin's Ink, that new-fangled stuff, don't yer know, that they presented to me to try—Piper's shop downstairs," thus he owned up, elevating it with a ludicrous over-the-fence-is-this-your-cat expression.

---

* For value of "g" see any standard text book.

The chief, straightening his back and face, softly enquired, "The kind that makes those bee-u-thiful black, very black lines?"

"Yes, sir, guess I got hold of an extra good bottle. There's a drop—only a drop—left at the bottom," and he handed it to the chief, looking as foolish as a man caught standing on his own foot. Misfortunes never come singly. Slip, plunk, splash—and the precious bottle took a personally conducted tour around our feet.

"Aisy," spoke the chief, twisting to me with a jerk, and with something of the lambent aurora of a smile pervading the purlieus of his mouth, "Aisy," he commanded, "emigrate down to Piper's shop and buy a pint and a half of Stiggin's Ink. Git anything to irrigate a pen." And he gave a last, long, resigned sigh not unlike a sand pump in deep thought.

"Yes, sir," was my response, already half out of the door, "shall I get the waterproof kind, sir?"

"Shure, to be shure," dreamily responded he, "procure th' amphibious kind. Maybe I'll want to wape whin I use it."

You will be expecting that by now Mr. Assistant was in a state bordering on nervous collapse. Disillusion yourself, please. Just as I was disappearing, he called, accompanied by his faithful eyeglass:

"Yes, and—I say—Easy," came the request, "heah's five and twinty cents to get me a fresh bottle, and look, see that—er!—see that they slit the quill so's a cove can jolly well write with it. Now go—there's a good chappy."

I went. Didn't I just!

From that time the Oriental product that had to be hand-churned was as extinct as the Great Auk, or the Dodo, or the Winged Crocodile, or the Millionaire Engineer, or the Dishonest Contractor.

It was gone, and with it the daily grind. Plans of same may be seen at the office of the Government Engineer. There's a time for everything—beshrew me else—but in this epoch of strenuous Rooseveltism, none for the hand-wrought ink. It is as obsolete as pyramidal duck eggs in a surveyor's office in this year of grace.

Petrified India Ink as an institution was interesting. It is not all uncelebrated and unsung, for a certain minstrel, albeit with broken voice and shivered harp, has it thus—

Conceive him if you can,
A rotary fist young man;
  An India-Inkety,
  Grind-at-the-sinkety,
Black-to-the-ears young man.

WHAT THE GRADUATES ARE DOING.

This section is conducted with a double object in view—First, to give the graduates professional news of each; secondly, to give the undergraduates an idea of the possible fields of employment open to them in the future.

Geo. H. Power, '01, is installing a sewage system at North Battleford, Sask.

A. L. Ford is government inspecting engineer on the G.T.R. at Prince Rupert.

R. S. Davis, '07, is with the Canadian Westinghouse Co. at their Winnipeg office.

E. M. Wood, '06, has joined the staff of the Hydro-Electric Power Commission..

W. K. Greenwood is resident engineer on Clinton, Ont., waterworks construction.

W. S. Pardoe, '04, has been appointed to the staff of the University of Pennsylvania.

T. H. Hogg, '07, last year demonstrator in Strength of Materials, is with the Ontario Power Co.

W. P. Linton, '06 and L. R. Wilson, '09, are with the Dominion Bridge Co. at Montreal.

F. W. Harrison, '05, is chief mechanical draughtsman of the New York Edison Co., at Brooklyn, N.Y.

F. C. Smallpiece, '08, is assistant manager of the Montreal office of the Canadian General Electric Co.

F. E. Prochnow, '08, is taking up Patent Attorney work with Wilhelm, Parker & Ward, Buffalo, N. Y.

W. V. Taylor, '93, is with the St. Lawrence Stevedoring Co.. Quebec for handling N. S. S. & C. Company's coal.

W. G. Hewson, '05, is with the Westinghouse Electric and Machine Co. in the Railway Engineering Department.

J. T. M. Burnside, formerly Chief of Location on the Canton and Hankow Railway, has returned to Canada.

J. G. McMillan, who was with Capt. Bernier for the last two years on the Arctic Expedition has returned to the city.

J. G. Fleck, '04, has forsaken the field of engineering and is a member of the firm of Fleck Bros., Limited, Vancouver.

J. H. Rychman, '06, is with the Chicago, Milwaukee & St. Paul Railway in the Bridge and Building Department at Chicago.

We regret to report the death of Milton Bates, '06. A full obituary will, according to our custom, appear in the final number of this volume.

W. H. Sutherland, '02, is with the Montreal Water & Power Co. in charge of operation of pumping plant—steam and electric —and distribution system.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published monthly during the College year by the University of Toronto Engineering Society

BOARD OF EDITORS

K. A. MacKenzie, B.A.Sc., '06	Editor-in-Chief
J. C. Murton, '10	Civil and Arch. Sec.
H. W. Fairlie, '10	Mech. and Elec. Sec.
C. G. Titus, '10	Mining and Chem. Sec.
W. D. Black, '09	Ex. Officio U.T.E.S.

Associate Editors

H W. Price, B.A.Sc., '01	Mech. and Elec.
P. Gillespie, B.A.Sc.	Civil and Mining
M. C. Boswell, M.A., Ph.D., '00	Mining and Chem.
W. Treadgold, B.A., '05	Railway

Advertising Committee

H. W. Tait, '09. R. Fuller, '11.
E. A. Jamieson, '10. J. Galbraith, '13.
Treasurer: F. V. Munro, '09.

Subscription Rates

Per year, in advance	$1 00
Single copies	20

Advertising rates on application.

Address all communications:
Applied Science,
Engineering Bldg., University of Toronto,
Toronto, Ont..

Editorial

Introduction '09-10.

This number of Applied Science begins the third year of its existence. It is expected that the healthy growth of the past two years will continue, and that its influence for good, both among the graduates and undergraduates will continue to increase. If it succeeds in keeping the alumni more closely in touch with the University and with each other it will have accomplished one of the main objects of its existence.

During the summer blank forms were sent to all graduates asking for a complete record of their experience. It is very necessary that this information should be in the Secretary's office. Some of the questions asked were, in the eyes of some, regarded as rather personal, but the graduate need not answer these unless he so desires. However, the record of experience is very necessary, continually cases are arising when the information asked for would be of mutual interest to the graduate and to the faculty. With it perhaps the authorities would not be constrained to go out of the profession when they wanted a superintendent of buildings, or out of the country when they want an expert report on engineering matters. With it we may be able to convince the business men of Canada that we can produce men who can and have handled engineering problems of the greatest magnitude successfully, and the legislature that an engineering college is a most valuable asset to the province.

Employment Bureau

The question of an employment bureau is a natural result of the information to hand, but is purely second to the general object. During summer we were able to place a great number of graduates—particularly experienced ones—and could have placed a great many more had they been available. We have at present a number of requests for experienced men and would advise all who are contemplating a change to fill in the blue slip and forward to the office.

New Laboratories

There is a general feeling of pride in the new Thermodynamics and Hydraulic Laboratories, which easily rank among the finest on the continent. Although hardly as complete and as extensive as those of Germany, described by Prof. Angus, in his paper on European Laboratories, yet sufficiently well equipped to give the students a thorough knowledge of the basic principles of mechanical and hydraulic engineering, and at the same time to give ample scope for research work. The question of research work is one that must be taken up and thoroughly discussed in the immediate future. The new laboratories will be fully described and illustrated in a future issue. It is the intention to open the new buildings officially in December. This year's freshmen class enters on the new four-year course. In numbers it is slightly smaller than its predecessor. This is explained neither by the increase in fees nor lengthened term, but by the rise in the standard of matriculation. The incompetents and the unprepared were weeded out more thoroughly and this year's class is among the most promising in the history of the Faculty of Engineering. On the whole, the changes in the curriculum have given general satisfaction. The new course in accounts and business organizations is welcomed, but general regret is expressed that the course in English has again been delayed. If the reasons are financial it is hoped that another year will see this very necessary side of engineering education receive its proper recognition.

THE ENGINEERING SOCIETY.

This year sees the affairs of the Society in the most healthy state of its existence. The Executive of '08-'09 stepped out leaving a considerable surplus in the treasury.

The incoming Executive, which has shown itself thus far to be a progressive one, was not slow to grasp this opportunity for expansion.

At the first meeting of the Faculty Council the President invaded the sanctum with two propositions and found that august body as usual willing to give full consideration to proposals emanating from the Society.

The first of these proposals was in regard to the rearrangement of the Faculty Library and the Supply Department. This room serves for the combined use of the library, reading room, supply department and office of paid secretary and assistant registrar, and was laid out apparently without regard to economy of space. Plans were submitted showing where all concerned, particularly the Engineering Society would be benefited by a change in the arrangement.

A committee was appointed which after considering the proposition gave the Society power to make the proposed changes. This change results in giving the Society the north side of the room, with a counter 24 feet in length and an opportunity to display the stock. This is a decided improvement over the old L-shaped counter and crowded corner of the original arrangement. A modern two-drawered cash register is much in evidence and a permanent sales clerk is employed and the department kept open at all hours.

We have developed here the ideal system of co-operative purchase and sales. We buy our supplies at lowest rates and sell at our own prices. For several years we have had printed and have sold printed notes of lectures. This year "Applied Statics" notes by T. R. Loudon have been bound and are offered for sale by the Society at cost price. We now meet with a demand from the Students' Book Department, which is properly speaking not co-operative, to hand over the sale of such books to that department. Needless to say we feel it an injustice to be asked to hand over a field which we have exploited, in this way. The Supply Department has become of prime importance in enabling us to carry out the undertakings of the Society.

The second proposal with which the Council was approached was to hold an exhibition or conversazione in connection with the official opening of the Thermodynamics and Hydraulic Laboratories.

The definite shape which this scheme assumed was that the four engineering buildings should be linked together. A pamphlet or book descriptive of and illustrating the features of the Faculty of Engineering should be published for distribution, and several thousand invitations issued for the first night of the function. All the buildings should be illuminated and decorated and everything in working order. The official opening by the Governors should take place in the new buildings and then all machinery set in motion through the buildings and experiments be conducted and the conversazione would be in full swing, with addresses being delivered, in various lecture rooms, of popular interest. Orchestras should be in attendance and refreshments served in the large draughting room.

The next afternoon the conversazione would be continued, and the buildings thrown wide open to the public. The final function would be our annual dinner, with an opportunity before the dinner for our guests to be conducted through the buildings.

The object is to bring the Engineering Faculty more in the public eye, to reach everybody from the cabinet minister to the apprentice boy, to show the public how their money is being spent for the industrial advancement of our country, and to show to the manufacturer, contractor, etc., how the graduate is being equipped to become a useful employee, and promoter of industrial enterprises.

It is needless to add that the Council at once grasped the full significance of the advantages to accrue to the successful carrying out of this scheme and have done everything possible to further the proposal, with Prof. Angus as chairman of the committee appointed jointly by the Council and the Society. The matter is now somewhat in abeyance pending a grant by the University Governors, but will be pushed with the greatest enthusiasm as soon as notification advising us of such a grant is received. The Engineering Society looks to the graduates for their active co-operation in making this function the great success it promises to become.

In view of the amount of work entailed by the carrying out of this proposal and for other reasons understood, but not mentioned, the Council refuses to give the official seal to the annual excursion. It is the wish of the Faculty that Sectional excursions be undertaken as offering greater educational value to the student. This policy has been approved by the Society Executive.

The first general meeting of the Society, October 6th, was largely attended, when an able and interesting address was delivered by W. J. Francis, C. E., on "The Relation of Technical Education, Personality and Character in the Work of the Engineer."

The three sections of the Society held their regular meetings on October 20th. Eugene Coste, M.E., addressed the Mining and Chemical Section on "The Origin of Oil"; C. R. Gulley, B.A.Sc., the Electrical and Mechanical Section on "Transformer Testing"; W. G. Swan the Civil Section, on "Railroad Location."

We have a number of requests for experienced men, particularly in the electrical and mechanical departments. If you contemplate making a change communicate with the editor.

Applied Science

INCORPORATED WITH

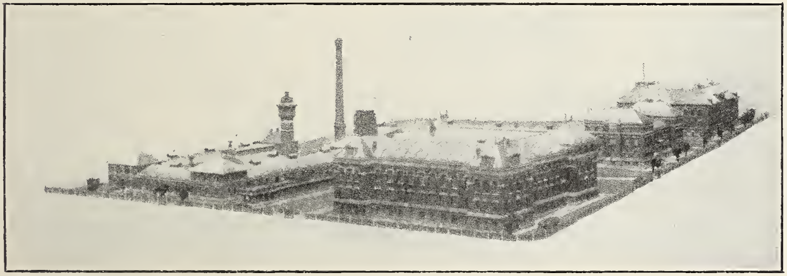
TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 3 DECEMBER, 1909 New Series Vol. 3, No. 2

EUROPEAN ENGINEERING LABORATORIES.

ROBERT W. ANGUS, B. A. Sc.

Professor of Mechanical Engineering, Dresden



General View of Buildings—Dresden.

Dresden is a city of well on to half a million people, is the capital of Saxony and is thus the residence of the King of that district. It is a city well known to English speaking people, mainly on account of the facilities offered for the study of music and art, and one of the finest art galleries in the world is to be found there.

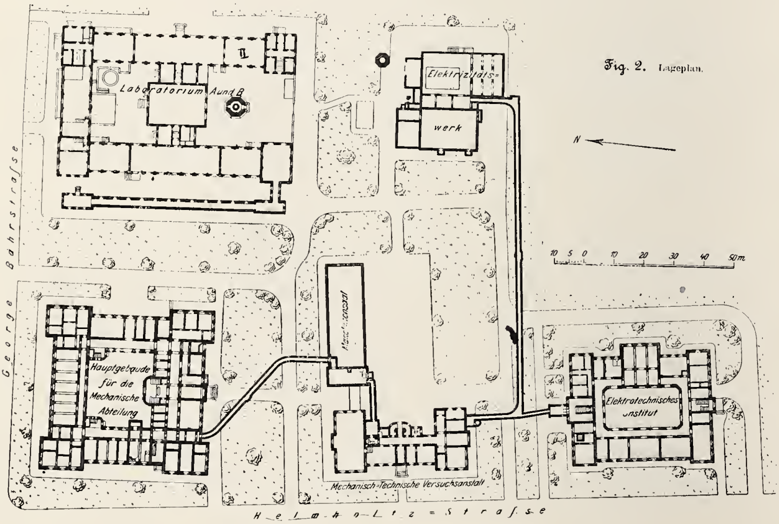
But it is not alone in music and art that there are great opportunities, for here one also finds a very large and well equipped Technical High School, and it is doubtful if there is a laboratory in Europe better arranged for undergraduate work. In my former article I have mentioned the superiority of the Berlin school, and certainly for research work the opportunities offered are exceptional. A glance at the list of apparatus, however, at once shows that many of the machines are of large power and size, and the writer does not believe that such machines are best fitted to the needs of undergraduate students on account of the difficulty experienced in grasping mentally the whole machine at once.

In Dresden, the machines are of fairly small size and power, so that the whole may be comprehended at one time and a clearer understanding of the work obtained. It is quite true that for research work the smaller machine may usually be used only to give relative results, yet the latter are instructive and in many cases quite as useful as the more absolute results obtained from large sized machines.

The Technical High School in Dresden has sprung from a Technical School established in 1828, which after various changes was formed into a Polytechnic School in 1871. The School obtained its present rank in 1890 and the right to grant the degree of Doctor of Engineering in 1900. It is under the control of a Rector appointed annually by the King, the name of the person so appointed being obtained by a vote of the professors. The total number of instructors, including professors and assistants, is about ninety-five.

The buildings of this School are quite new, having been completed only about four years ago at a cost of 5,500,000 marks ($1,320,000), and the whole institution is one of the finest examples of a modern Technical School to be found anywhere. There are in all five buildings: 1. The main building; 2. The materials testing laboratory; 3. The electrical laboratory; 4. The steam, gas and hydraulic laboratories; 5. The station for generating electric light, heat and power.

All of these buildings are of fine construction and are neat and well planned, but one does not see such fine architectural effects as were in evidence in Berlin. The cuts reproduced here give some idea of the general nature of the buildings and their arrangement on the grounds. These cuts are taken from a description of the buildings published in 1905 in the "Zeitschrift des Vereines deutscher Ingenieure."



Plan of Grounds—Dresden.

1. **The main building.**—I shall now give in some detail a description of the buildings and shall begin with the main building. This is shown on the lower left hand corner of the plan and is 187 ft. long and 184 ft. wide with a space 85 ft. x 72 ft. in the center left open for light and air. It is three storeys high and in addition has a good basement. The height of each of the two main storeys is over 17 ft. and of the basement about 11½ ft. The ground floor is occupied by offices, large lecture and draughting rooms, and the collection of models for kinematics, engine work, etc.

The first and second floors are used for similar purposes and contain a number of lecture and draughting rooms and some collections of models as well as some libraries and laboratories.

A very interesting feature of this building is a collection of iron and wood-working machines. The light well, already referred to, is covered over with a glass roof, making a beautiful bright room about 85 ft. by 72 ft. Various manufacturers are invited to lend machines to be exhibited in this room and these machines are set up and operated as in a regular shop. Students come in and study the machines, of which they may have catalogues, and they thus get a good knowledge of a great variety of tools without great expense to the School. Whenever a machine is sold it is of course removed, but manufacturers seem to find it to their advantage to keep the space pretty well filled up.

2. **The steam, gas and hydraulic laboratories.**—The laboratories "A" and "B" shown on the upper left hand corner of the plan are for the steam, gas and hydraulic work, and, as will be seen, cover a fairly large area. The laboratories are in charge of Dr. Mollier, who is a well-known writer on thermodynamic subjects and whom it was my good fortune to meet. The work on the design of steam and water turbines is taken by Prof. Lewicki.

The building may be described as consisting of a front part 170 ft. wide and 34 ft. deep, from the back of which run two wings each 170 ft. deep and 33 ft. wide, these wings being connected together about the middle of their length by a part which is about 100 ft. long with a mean width of about 55 ft., and which serves mainly for the boilers. Attached to the side of the building is a smaller structure 250 ft. long by 11 ft. wide used for a hydraulic canal.

(a) **The steam engine and boiler equipment.**—On entering the laboratory from the Director's office one finds a room containing the refrigerating and similar machines. A 16 H. P. motor drives an ammonia compression machine which is complete with condenser, etc., occupying most of the room, but there is also space for a gas fired steam boiler with feed pump and a liquid air machine

Passing into the next room, which is really the steam engine laboratory, there is found a 150 H.P. triple-expansion, horizontal steam engine, complete with jackets, condenser, reheater, etc., and three different types of valve gears. The air pumps and condenser are placed below the engine room floor in a basement, and the design of the crank shaft is such that the angles between the different cranks may be altered at will. A dynamo driven by belt serves to produce the load. This room further contains a vertical marine cross-compound engine of 150 H.P. at 200 revs. per min. with jacketed cylinders, the power being absorbed by the dynamo mentioned above or else by means of an Amsler-Laffon hydraulic dynamometer.

The remaining apparatus consists of a 35 H.P. tandem engine for superheated steam; a duplex engine of 26 H.P also for superheated steam, both engines being capable of working with steam at 150 pds. pressure superheated 400° C. There is further a de Laval turbine of about 20 H.P. The whole room is served by a six ton crane.

Adjoining this room is a large lecture room with a specially arranged table so that quite elaborate steam and hydraulic experiments may be made before a large class. Such a room, although costly, is a very valuable addition to an engineering school, enabling lectures on thermodynamics and hydraulic subjects to be illustrated in the same manner as is common with lectures on physics and chemistry. The apparatus and cloak rooms are situated close to this lecture room.

This completes the description of the east wing and we now return to the engine room and pass into the part which connects the centre of the east wing with the centre of the west one. This part contains the workshop for the laboratories and the boiler and gas analysis rooms. In one room is the workshop; in another the superheaters and accessories; in another the apparatus for gas analysis, while the largest room contains the boiler. This latter room is over 60 ft. by 44 ft., lighted mainly from the roof and having a very fine tile floor. There are three boilers of good size: one by Wolf having a heating surface of 590 sq. ft., a much larger water tube boiler and a smaller boiler. The necessary scales for feed water and coal have been properly provided and well arranged.

Entering now the west wing and passing down to the south end we find in the two southerly rooms the hydraulic apparatus which will be described later. The central room is quite large and contains a pumping engine having a capacity of about one cubic foot per second against a head of 328 ft. The pump is steam driven and is arranged so that it can be compounded at any future time, and may discharge into a vertical tank about 6 ft. diameter and 16 ft. high in the room, or if desired it may pump water into an elevated reservoir which produces a static head of about 80 ft. This pump is specially designed for research work.

The method of supporting the elevated reservoir is somewhat interesting. For the experimental boilers already described a special stack has been constructed, and around this stack near the top is placed the reservoir, a very convenient though somewhat clumsy looking arrangement.

In addition to the pump this room also contains two small-sized air compressors, an engine and other apparatus. The room is also used for research work on air and other fluids, and special test floors have been provided, and the assistance of a 3½ ton traveling crane makes the handling of apparatus easy.

The next room to the north contains the air compressor, air meters, and similar apparatus. The air compressor is three-stage, having cylinders of 10-inch stroke, and is belt driven from a motor. It contains many interesting features and is much used for research work.

An experimental locomotive has been installed in a special room as there was no available space in the laboratories.

(6) The gas engine equipment.—There are two floors in the front part of the building which are devoted largely to gas engine work. In order to save space I shall merely name the machinery in this part, which comprises the following: Three small gas engines of old type; large gas and air meters; 8 H.P. Deutz gas engine; 4 H.P. vertical gasoline engine; 8 H.P. de Dion automobile engine; 8 H.P. Koerting engine; 70 H.P. Deutz gas engine, which is supplied with gas from a pressure gas producer in a separate room outside. The gas holder for this producer plant is also used in calibrating gas meters by forcing a measured quantity of air through the latter.

Nearly all the gas engines are fitted with magnetic brakes of neat design which give very satisfactory results. These brakes consist of two bars, slightly longer than the diameter of the fly wheel, which are mounted by bearings on the crank shaft. Between these bars at either end an electro-magnet of adjustable strength is placed which has an iron core almost touching the wheel. The horse power of the engines is measured by placing scales under the end of the bars and reading the pressure produced.

In addition to the above gas engines there is in the same laboratory a steam plant specially constructed for research work. This plant consists of a boiler, independently fired, superheater, and engine of about 30 H.P. arranged with jackets and all pumps and apparatus for measuring the heat losses and efficiencies.

A complete machine shop and an experimental room in which is an injector testing apparatus completes the equipment of this part of the building.

(c) The hydraulic equipment.—At Charlottenburg the hydraulic laboratory is situated on a flowing stream of water and hence is contained in a very compact building, while at Dresden, on the other hand, no such stream is available, so that the supply of water for all work has to be obtained by direct pumping. On referring to the general plan of the grounds a narrow building will be noticed on the west side of the laboratories A and B which is connected to the latter at the south end. This building is about 18 ft. high and contains two open channels, one on the roof and one at the bottom, each of which is about 260 ft. long, 6½ ft. wide, and 3 ft. deep, and both are used for the double purpose of conveying the water to and from the turbines and for experiments on open channels. As the upper channel is exposed to the atmosphere it cannot be used in frosty weather.

The surface of the water in the upper channel is 13 ft. above that in the lower one, and as the water is used for reaction turbines this difference of level is the available head. The supply for the turbines is maintained by two large motor-driven centrifugal pumps, each of which will deliver about 21 cu. ft. per sec. at a speed of 360 revs., the head being about 13 ft., as above stated.

In addition to furnishing valuable research work on open channels the water is also used for suplying turbines in the laboratory, of which there are three of the reaction type, viz.: (a) a Francis turbine built by Voith in 1901 complete with governor and designed for 28 cu. ft. per sec. at 131 revs. per min., the diameter of the wheel being about 3 ft.; (b) a Jonval turbine built by the Meiszener Turbinenfabrik having the same capacity as the Voith turbine, the speed being 110 revs.; (c) a spiral Francis turbine with horizontal shaft by Amme, Giesecke and Konegen, of Brunswick, having a runner 23¼ in. diameter and a discharge of 25 cu. ft. per sec. These wheels are all set up conveniently for experimental work, and a place is left for the installation of a new turbine or for commercial testing.

In other rooms of the building the following hydraulic apparatus is to be found: An impulse wheel of fairly large size, which has just been put in; two hydraulic engines; several pumps; hydraulic rams; measuring canals and other apparatus. The large piston pump and elevated reservoir have already been mentioned.

It has been possible to describe the equipment very briefly, and one cannot convey here an adequate idea of the completeness of the laboratories described. The variety and suitability of the different pieces of apparatus make one feel that these laboratories are of the very highest order and that they offer excellent facilities for graduate and undergraduate study.

3. The laboratory for testing materials of construction.— The building containing this laboratory is located directly south of the main building and consists of two parts connected by a passageway, the front part being about 148 ft. long and 68 ft. deep and four storeys high, while the back part is L shaped 135 ft. by 110 ft. and one storey high.

The front part of the building on the basement floor is occupied by laboratories, special rooms being set apart for: (1) tensile and compressive tests; (2) tests on stones of various types; (3) refrigerating machine for cold tests on cement, etc.; (4) cement testing; (5) preparation of cement for testing, etc. These rooms contain very excellent apparatus for the purpose in view, amongst which may be mentioned the following: 100 ton machine for the testing in any way of very long specimens; 300 ton press by Martens; 50 ton Martens testing machine; 1,000 ton press for compression; 50 ton Mohr and Federhaff testing machine; tensile and also torsion testing machine by Amsler-Laffon for 25 tons tensile stress; 150 ton Amsler-Laffon press for bending tests; machine by Amsler-Laffon for cold bending tests;

several machines for dressing stones for testing; carbon dioxide refrigerating machine and accessories for showing the effect of cold on cement and other materials; cement testing machines; mixing and other machines for cement, and other apparatus.

The ground floor of this front part is mainly used for offices, library and one or two small laboratories, while the two upper floors contain the laboratories for oil-testing, technical chemistry and also a lecture room, the collection of models for this department, the metallographic laboratories, photographic rooms and other similar rooms.

The back part of the building is divided into three large rooms and five smaller ones. On entering from the front the first small room contains oil and water pumps and accumulators for operating the testing machines. Most of the machines in the basement of the laboratory already described are operated by oil or water pressure, and are connected to a reservoir with an accumulator, the pressure being maintained by pumps. All oil and water, after use in the machines, drain back to the room mentioned, where the fluid is filtered and again pumped back into the pressure side of the system. The operation of the whole system is automatic and provides an admirable arrangement for cleanliness and convenience.

Next to this is a large room containing three lathes and a corresponding number of other machine tools for making apparatus and specimens. There is also here a very large testing floor with a pit below 15 ft. deep, on which gas and gasoline engines and other machines are tested, and which may also be used for tests on machine elements and transmission machinery. For the latter purpose there is a line shaft which may be belted to a 50 H.P. motor or a 10 K.W. generator in a separate room, the machine used depending on which way the power is being transmitted. Necessary rheostats, etc., are also provided.

The other rooms are used for melting materials, a complete smith shop, various tools, and a complete automobile testing plant in which the power is taken up by dynamos.

One large room, specially set apart for research work on materials, was being used for testing concrete beams when I visited Dresden. A great many beams had been set up on supports and by a most ingenious and simple device these beams were being automatically subjected to many hundreds of applications of concentrated central load, the number of applications before failure being recorded.

Several small buildings in the grounds were also used for fire tests on materials.

(4) **The electrical laboratory building.**—This building is 125 ft. wide and 157 ft. long, is four storeys high, having a large central light well covered at the top of the building with a glass roof. The lighting of the building is almost perfect, as every room is on an outside wall, and only the ground floor under the light well is used. This latter space is used for heavy dynamos and motors. This whole laboratory is very well equipped and con-

tains apparatus for instruction in high and low tension, as well as in direct and alternating currents. Instruction is also provided in telegraphy and signaling.

There are also several lecture and draughting rooms, library, etc., which it is impossible here to describe in more detail.

The building cost $170,000 complete with its equipment.

(5.) **The central heating and lighting plant.**—It is scarcely in place to describe this amongst the laboratories, so that I shall only mention it. This building contains a boiler room 49 ft. by 56 ft., an engine room 62 ft. by 43 ft., an electric accumulator room and a wash room. The plant consists of two steam turbines with direct connected generators each of 150 H.P. and two large boilers; the chimney is 148 ft. high.

It is with great reluctance that I close this brief description of this very important School which presents such possibilities in laboratory and general instruction, and which seems to be planned on broad and generous lines so as to offer to students the greatest possible advantages. It is an institution of which any country may well be proud.

Munich.

The Technical High School in Munich was established as a Polytechnic Central School in 1827 and was raised to the grade of a Technical High School in 1877. In this institution there are about 2,800 students and a large staff, although the number of students per instructor is higher here than in most German schools.

I was fortunate in meeting the Rector, Dr. Moritz Schroeter, who has charge of the steam and gas engine work and whose name is well known in this country in connection with engine testing. It was to this institution also that Dr. Lindé, the inventor of the refrigerating system known by his name, belonged.

The heat engine laboratory here is without much interest, as it was installed over thirty years ago by Dr. Lindé and is now much overcrowded with many old machines, the only new machine being a small Diesel oil engine. Plans are now being prepared for a fine new building which will be on a scale similar to that of Dresden.

The power plant in this institution consists of two 40 H.P. Diesel engines which work steadily and give no trouble.

However, I went to Munich mainly to learn something of the work being done in connection with superheated steam and along other similar lines. This work is under Dr. Knoblauch, the Professor of Technical Physics, and is carried out in a building some distance away from the main Technical School buildings. The place resembles an old shop and one would never look in it for a laboratory, as it is not inviting, but the results being obtained here are fully as reliable as those from the very best laboratories. Dr. Knoblauch showed me with very much pride the apparatus he is using on superheated steam, but I shall not take the space to describe it here.

Considerable other research work is being done here also, and one could not go away from the place without feeling a good deal of pleasure in meeting men who were in such a quiet way and under such uncomfortable conditions accomplishing so much.

Undoubtedly when the new laboratory at Munich is completed it will be quite up to the standard of other German Schools.

Darmstadt.

On leaving Munich, the nearest institution was the great School at Zurich, but as the German Schools are now under consideration I shall leave this for the present. On leaving Switzerland, lack of time forced me to pass the cities of Stuttgart and Karlsruhe, with their Technical Schools, and to visit only the one institution at Darmstadt.

Darmstadt is a small city of less than 100,000 inhabitants, so that one would not expect to find here a great institution of learning, and yet, like Dresden, the School is one of the newest and best equipped in Germany. The Technical High School at Darmstadt was founded as a Technical School in 1836, changed to a Polytechnic School in 1868 and raised to the grade of a Technical High School in 1877.

The attendance at the institution has increased very rapidly, reaching a total of nearly 2,000 at present. As in other Technical Schools the staff is also quite large, there being 39 professors and 75 lecturers and other assistants, but the number of students for each member of the staff is rather larger than is usual in Germany.

The buildings and laboratories are quite new, the oldest of them having been put up in 1895, but from 1903 to 1908 buildings went up very rapidly, the new buildings including amongst others the steam and hydraulic laboratories and the gas engine and strength of materials laboratories, the engineering laboratories being thus quite new. All the separate buildings are joined into two large blocks separated by a street, and the buildings are very beautiful both inside and outside, the whole suggesting that an engineer can be taught a good deal in the artistic line by example, even if he has not the time to gain it in the lecture room.

On one side of the street above mentioned is the group containing the main building, the materials testing and gas engine laboratories and the steam and hydraulic laboratories, while on the opposite side are the laboratories for physics, chemistry and electricity.

(1). **The main building.**—This building, exclusive of an attached wing, which will be mentioned later, is 256 ft. by 292 ft., the inner parts being lighted by means of two large light wells in the centre of the structure. There are four floors in actual use although a fifth floor is also partially occupied. The building contains part of the hydraulic laboratory and a collection of hydraulic models, various other collections of models, professors' rooms, a number of draughting and lecture rooms, rooms for mineralogy and geology, the library, executive offices and other similar rooms. Both the lecture and draughting rooms are quite extensive; of the former there are ten in the main building, with a total seating capacity of nearly 1,800, the largest holding 366 and the smallest 72 persons, while for draughting rooms probably about one-sixth of the entire floor space in the building is used.

The part of the hydraulic laboratory in this building is of interest and may be mentioned. This laboratory has a floor area of 10,760 sq. ft., which is divided amongst several rooms. The largest of these is 127 ft. long and 59 ft. wide, with a basement under part of it. This room contains a rectangular trough 98 ft. long, 8 ft. wide and 7 ft. deep, arranged for experimental work, and a model room close to it enables models to be prepared and placed conveniently in the tank. There is also an elevated tank having a capacity of 1,000 cu. ft., to which water is supplied by motor-driven pumps having a maximum discharge of about 90 Imp. galls. per sec. The laboratory is further provided with pipes, etc., for testing and research work, and is so arranged that a model river with different grades of bed may be caused to flow on a broad floor 80 ft. long.

(2.) The gas engine and strength of materials laboratories.—At the back of the main building is a wing, already mentioned, which is in two parts, one part 55 ft. wide by 160 ft. long, and the other part 65 ft. by 95 ft., the former having four floors and the latter only one. This whole wing is used almost entirely for the laboratories for strength of materials and gas engines and for draughting rooms, collections of models, offices and other like purposes, but it is with the laboratories that I wish to deal. The space occupied in the large part of the wing by these laboratories is set apart for cement testing and metallographic work. The smaller part of the wing is divided into four rooms; one room about 65 ft. by 32 ft. being used for testing machines; one room 55 ft. by 26 ft. for gas engines; a small room for a gas producer and the rest of the building for machine tools and tools for preparing specimens for testing.

Of the testing machines the following may be mentioned: A 100 ton large horizontal machine, a 5 ton, a 30 ton and a 50 ton machine; a 150 ton Amsler machine; a 400 ton Martens machine; a 50 ton tensile machine, and a number of others. The equipment includes also a full and complete cement-testing laboratory furnished with refrigerating machine for cold testing.

The gas engine equipment is in two rooms, one of which contains the suction gas generator. This generator is properly arranged for testing and is suspended from a scale beam by which the total weight of the generator and contents at any time may be found, so that by taking successive weights the fuel burned per hour may be determined with considerable accuracy.

The second and larger room contains the gas engines, of which there are a 20 H.P. Koerting engine for suction or city gas, an 80 H.P. Deutz engine, a Diesel motor, a two cycle motor of 16 H.P., and two smaller engines of 8 H.P. and 2 H.P. respectively. There are, of course, the necessary calorimeters, thermometers and other small apparatus, and as the laboratory is quite new it is well arranged and equipped.

(3.) **The steam engine and boiler laboratories.**—The steam engines and boilers in this laboratory are used for light, heat and power as well as for experimental purposes, so that the units are fairly large. The steam engine room is 111 ft. long and 57 ft. wide, having a basement under the entire floor and a gallery running completely round. The height of the building in the centre, above the main floor, is nearly 45 ft. The room is very well lighted both from sides and roof and is served throughout by a 6 ton traveling crane. This room contains the following machines: A horizontal single cylinder engine of 40 H.P.; a horizontal cross-compound engine of 100 H. P. arranged for experiments on the valves, etc.; a vertical cross-compound Sulzer engine of 120 H.P.; a vertical single-cylinder engine; a vertical tandem-compound engine of 200 H.P.; a 5 H. P. De Laval turbine; a 100 K.W. radial flow steam turbine; a Brown-Boveri-Parsons steam turbine of 250 K.W.; two surface condensers with cooling surfaces of 240 sq. ft. and 640 sq. ft. respectively, also with the necessary pumps. In addition to the above there are several pumps, viz.: Differential piston pump for 750 pds. press.; a three throw pump for 225 pds. press. and 1 cu. ft. per sec.; a high pressure six stage centrifugal pump by Escher, Wyss & Co. for 40 cu. ft. per min. at 320 ft. head; and in addition a horizontal, belt-driven Borsig air compressor requiring 50 H.P. to operate it at full load. There is also a good arrangement of pipes so that complete experiments on the flow of steam and air in them may be determined, and at the present time considerable work is being done on steam nozzles, the facilities for such work being exceptional.

The laboratory also contains a large cooling tower 22 ft. long with forced draught, built by Klein, Schanzlin and Becker, Frankenthal. There is also a very extensive collection of gauges, calorimeters, gas sampling and testing apparatus, indicators, etc.

The accompanying photograph gives a good idea of the general arrangement of the interior of this laboratory.

The boiler room is 62 ft. long and 57 ft. wide and contains three boilers each having 860 sq. ft. heating surface, and all are equipped with superheaters. There is also an independently fired superheater and all necessary feed pumps, which are all of very good type, and further a small air compressor and several injectors.

The chimney is 150 ft. high by 6 ft. diam. This laboratory is in charge of Prof. Gutermuth, whose assistant, Dr. Watzinger, very kindly gave me much help in seeing it.

(4.) **The water turbine laboratory.**—As has been already stated a general hydraulic laboratory is located in the main building, so that the one now under consideration is for turbine work almost entirely. An interior view of it is shown here, which gives some idea of the general arrangement. The laboratory, which is under the control of Prof. A. Pfarr, who has written a very able book on his chosen subject, is 111 ft. long and 41 ft. wide.

For the experiments in this room three supplies of water are available: (1) A volume of 35.3 cu. ft. per sec. at a head of 16 ft., which quantity is obtained from two pumps by G. Schiele and Co., one of these pumps having double the capacity of the other, and both being belt-driven from motors. (2) A supply of 0.7 cu. ft. per sec. at a head of about 200 ft. obtained from the Escher Wyss centrifugal pump in the steam laboratory. (3) A supply of about 0.3 cu. ft. per sec. at a head of nearly 1,000 ft. obtained from a piston pump in the steam laboratory.

The Steam Engine Laboratory—Darmstadt.

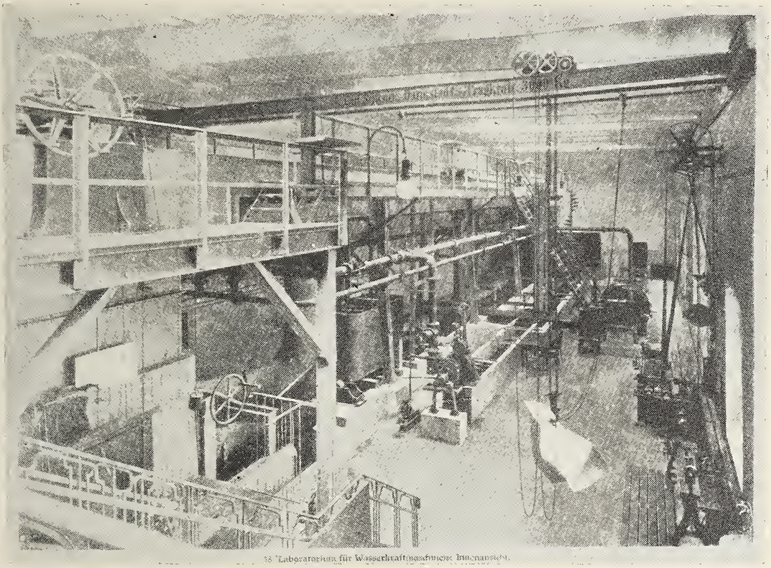
The first mentioned pair of pumps draw water from a well and deliver it into an open steel flume about 5 ft. wide running nearly the full length of the laboratory. This flume will carry water to a depth of about 27 in. and it is from it that the large reaction turbines are supplied, as it is arranged for this purpose as well as for research work. After passing through the turbines the water is returned to the well by a steel flume in which is a measuring weir. There are two turbines, one with vertical shaft and the other a Voith turbine with a 19 in. runner delivering about 13 H.P., the water from the latter turbine being measured in a separate flume 3 ft. wide discharging into the well.

The second supply drives a Pelton wheel made by Breuer and Co. delivering 11 H.P. at 200 ft. head, while the third supply is used on an impulse wheel built by Briegleb, Hansen and Co., which is capable of delivering 22 H.P. at 1,000 ft. head.

Some very excellent and commendable work is being done in this laboratory, but space prohibits further description.

The entire laboratory is served by a 7,000 lb. traveling crane.

If this article were not already so long it would have been possible to describe the other buildings, including those for chemistry, electrochemistry, electricity, physics and machine elements, but enough has been given to afford a good idea of the nature of the institution and the grade of work that may be done there.



The Water Turbine Laboratory—Darmstadt.

SOME NOTES ON THE DESIGN AND CONSTRUCTION OF AN INTERCEPTING SEWER.

A. C. D. BLANCHARD.

About three weeks ago a gentleman prominent in University circles, had occasion, at a gathering of Applied Science Alumnae, to refer to a pond in the vicinity of Dublin. The pond was described to so far stagnated that, to quote the exact words, "it emitted a stench."

His next remarks were directed to Toronto Harbor. While he hastened to deny any inference, his hearers drew their own conclusions.

It was thought when commencing this paper to take up the design of an Intercepting Sewer in the abstract, illustrating the construction by that being carried on at present in this city. I decided, however, that it would be more interesting to the members of this Society if I confined myself principally to a description of some of the features of design and construction of the work in hand. In passing I wish to mention some of the primary considerations involved in its design, which can be applied to the design of any sewer.

The first thing in designing any sewer is to decide on the amount of sewage which will be admitted. Dealing with sewage proper; that is, exclusive of sub-soil and rain water, the flow is governed by the water consumption and the population within the drainage area.

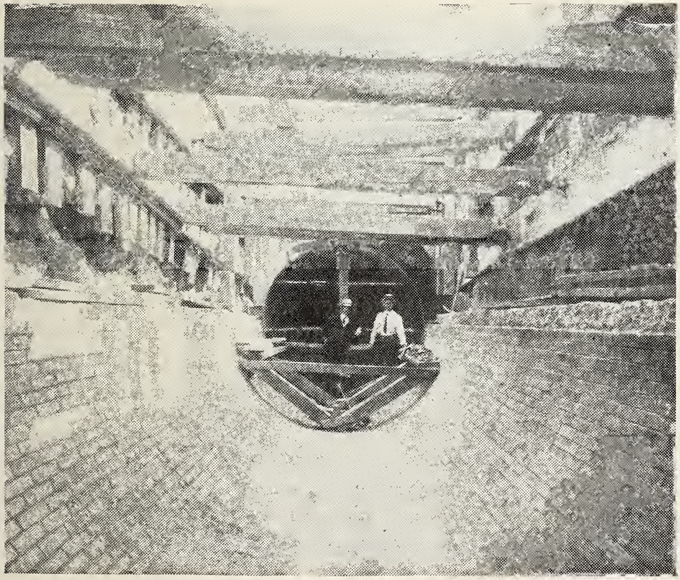
The flow varies considerably with each hour of the day and with each season of the year. The maximum and minimum is usually a certain definite percentage of the average intensity and can usually be ascertained for each particular sewer. The larger the district or the number of districts, the more even is the flow of the whole system. The reason for this is obvious on account of the diversity of sources from which sewage is derived. In the same way in a trunk sewer, which has intercepted a number of smaller sewers, the variations are not nearly so marked as in each branch sewer.

If the sewer is classified as belonging to the combined system, the rainfall, water used for street-cleaning purposes and drainage of natural water courses must also be considered. In most combined systems, the sewers are designed for the rainfall alone, as the sanitary drainage is very small in comparison.

It is beyond the scope of this paper, I think, to enter in upon the discussion of the theory of hydraulics applied to sewer design. The question of rainfall and run-off is a subject also in itself, and I shall not do more than mention it in passing.

With regard to governing velocities in sewers in general, the best practice places the velocities from 3 to 10 feet per second. If the slope of the ground is such as to give a greater velocity than the latter figure, the sewer is laid flatter and "drops" or "ramps" are provided at intervals. The minimum velocity allow-

Excavating for the Intercepting Sewer.



Completed Invert and Steel Forms Set for Arches.

able in an intercepting sewer, owing to the comparatively constant volume of flow is less than would be proper in branch sewers. In any event, the minimum velocity should not be much below 2⅓ feet per second. Toronto interceptors will have such a minimum velocity of flow and a maximum velocity of about 4 feet per second.

The existing sewers of Toronto are laid according to what is known as the "Perpendicular System" and are built to carry a combined flow of both sanitary and storm water sewage. Laterals on side streets feed each main sewer, which in turn discharges through its own outlet.

Each principal street running south between Bathurst and the Don River has a main sewer which discharges into the Bay. The Garrison Creek sewer, 8 feet in diameter, discharges into the Lake near the Old Fort and the Rosedale Creek sewer, 6 feet 6 inches in diameter, runs from the high level pumping station above the C. P. R. tracks near Avenue Road and discharges into the Don. This sewer will take all the drainage from north of the C. P. R. tracks as far west as Bathurst Street, and possibly further.

East of the Don the districts are not built up much, so the dry weather flow (or sanitary sewage) is very small in amount.

The constant flow of the total volume of the city's sewage, carrying day by day over 20 million gallons of sanitary sewage and factory wastes into the Bay, converting this comparatively small land-locked body of water into a huge settling basin, or septic tank, stirred up during the summer months by countless steamers and ferries, fermenting and aerating and purifying itself as best it can; bestowing a delicate mustard tint on what should be a beautiful, calm blue basin; strewing on the surface patches of paper, straw, oil, and many different kinds of organic wastes, makes the condition of portions of the harbor more or less intolerable during the summer months. In addition to this, the Garrison Creek sewer now carrying 8 million gallons per day, and with its ever increasing flow, discharges into the Lake at the Old Fort, which will ultimately form a part of Greater Toronto's Park System, and the smaller sewers in front of Exhibition Park also add their quota.

These considerations, together with the necessity of placing beyond doubt the purity of the water supply taken from outside the Island near its western end, made it imperative that something should be done to rectify evil conditions which have been steadily growing with the growth of the city.

The need of these main drainage works have been in the public eye for many years, but it was not until 1908 that the by-law for the appropriation of $2,400,000 for the carrying out of this work was ratified by the people.

Our problem then is simply described. To free the water supply from contamination and the harbor and lake front from pollution.

To do this it is planned to intercept all the sewers practically across the whole breath of the city, and divert what is known as the dry weather flow into interceptors, conducting the discharge easterly to the disposal works, situated near the Woodbine race course. The futility of endeavoring at a reasonable expense to intercept the storm water in time of an intense rainfall, which then amounts to a hundred times the dry weather flow, is apparent. A heavy rainfall occurs only a few times a year, and the dilution of the sanitary sewage by the rain water is so great that there would be practically no pollution of the harbor. It is true that in time of a heavy rainfall the discharge is highly colored and frequently full of suspended matters, straw, paper, etc., but the finer particles are mostly inorganic; and with adequate screening the coarser matter may be kept from discharging into the harbor, some remaining on the screens and the balance being diverted through the interceptors to the disposal works.

We have allowed, therefore, in our designs, to carry all sewage to the disposal works to the extent of about 200 gallons per head, although this figure varies with different districts as will afterwards be explained, and the present interceptors are designed large enough to perform this function for a period of twenty years. A new generation may then be required to provide an additional interceptor, unless the water consumption per head is reduced.

The present scheme embraces the construction of two interceptors. One, the high level interceptor, is the larger and intercepts over two-thirds of the total sewage. This carries its sewage on minimum grades varying between 1 in 1,600 and 1 in 3,200, and discharges by gravity into the disposal tanks. The second, known as the low level interceptor, is smaller and takes only that portion of the sewage which cannot be intercepted by the high level. The low level sewage has to be pumped at the disposal works into the tanks.

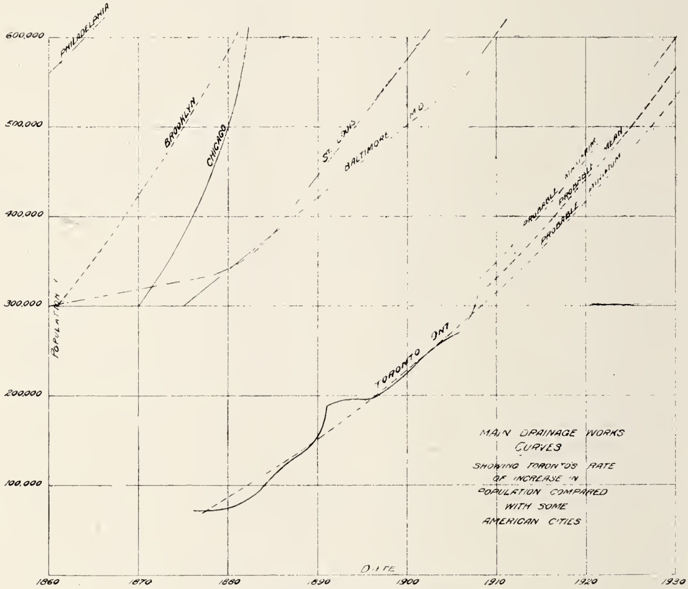
Branches are run to intercept the Garrison Creek sewer and the Rosedale Creek sewer.

The disposal works consist of screens, tanks, and an outfall to the lake. It is not my purpose to discuss this portion of the work. This work is in charge of my colleague, Mr. F. W. Thorold, a graduate of the University, and I trust that you will persuade him to tell you at some time of the Disposal of the Sewage, with its exceedingly interesting problems in design, construction and methods of operation.

And now for a word or two regarding the design of the interceptor.

The data by which the probable population of the city in 1930 was forecasted was contained in my report to the City Engineer dated May, 1908. The year 1930 was agreed upon as being a reasonable time limit for present provisions. The police census was obtained as far back as possible, and also the census arrived at by the Assessment Department. Curves were made from these data and produced, and combining the results obtained from these different means, which checked very closely, the conclusion was arrived at that the total population would be somewhere between 550,000 and 600,000. The curve representing the growth of this city's population was compared with the known population of curves of other cities and found to approximate that of Baltimore.

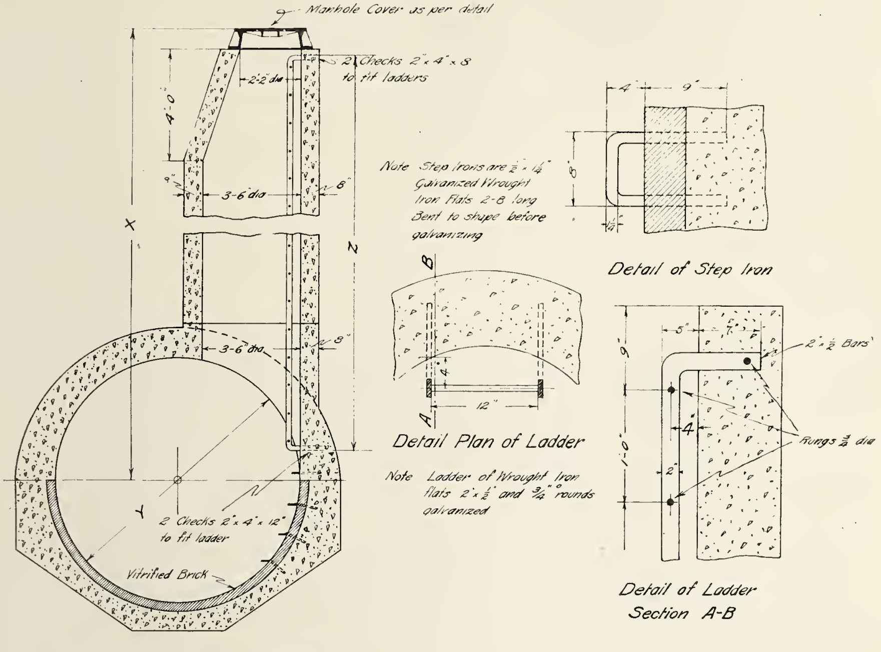
Having settled, therefore, upon the probable population for the whole city, the next and more difficult task was the distribution of this population throughout the existing sewer districts. Each important existing sewer running from north to south to the Bay takes the drainage from certain definite areas. All sewers of the city were plotted on a map with their directions of flow, and some 50 different sewer districts were outlined accordingly. As the probable ultimate population of each ward had already been ascertained, it was possible to settle upon the probable population of each sewer district. Having now obtained the probable population, it was left to decide upon the amount of sewage used per head. This amount, of course, varies greatly among different classes of the population. For this purpose a party of skilled workmen was sent out in charge of a member of the staff, and gaugings were made of the flow of all the sewers at their intersections with the two interceptors. This consumed a period of three months, working night and day. It was possible to judge closely the sanitary sewage of each district after obtaining the actual dry weather flow after the above manner.



Population Curves

In the meantime in the office the drafting staff was busy making the preliminary designs.

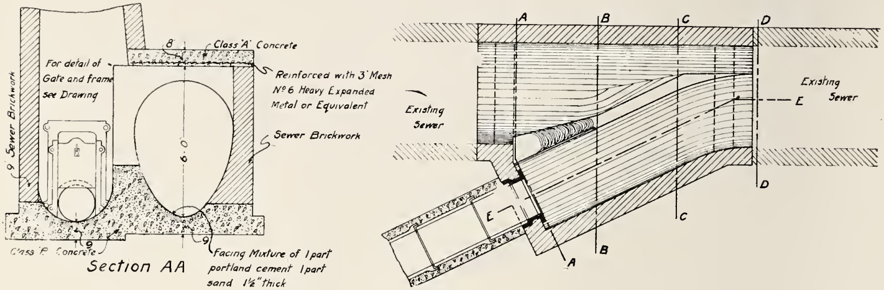
Typical drawings of manholes, junctions and other structural details were being prepared, and specifications were being written and printed. Surveys of the streets, which the route would probably follow were made by a field party. Water mains, electric light and telephone conduits, gas mains, existing sewers, areas under the sidewalks, pavements, curbs, gulleys, catch basins and manholes were located, and the total bulk of information thus obtained was plotted on the plans and profiles. Fig 2 represents a typical street intersection showing underground obstructions.



Section through Interceptor Manhole

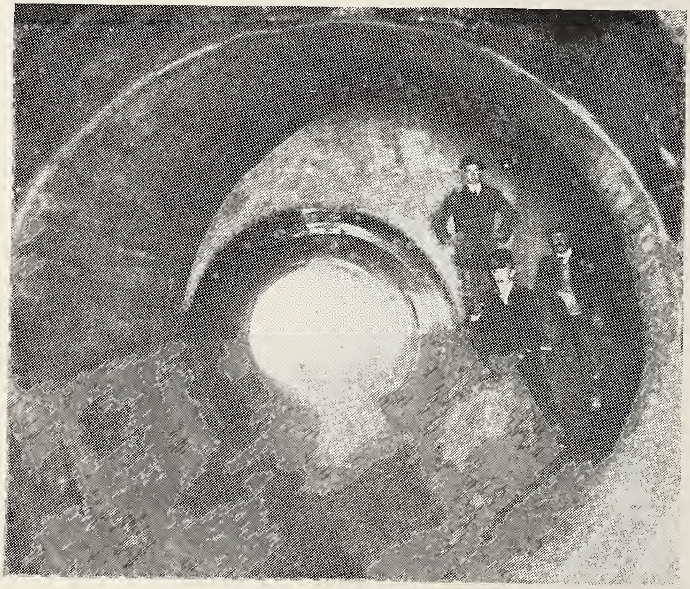
Details of Manhole

After the gaugings were made allowance was made for rainfall and the sizes, grades and route of the interceptor finally chosen. In order to intercept the dry weather flow alone, and to allow storm water to continue to the water front by the existing sewers, at a point where each sewer is intercepted is built a bellmouth. Each bellmouth is provided with a weir, so that the dry weather flow may be diverted into a smaller pipe leading to the interceptor. A gate is provided in front of the smaller part to regulate its capacity and the weir also is capable of adjustment to suit the conditions, which will be subject to change as the discharge of the sewer increases in coming years. The principal features of the design of this bellmouth will be seen from an examination of Fig. 3. The exact line was then laid down on profiles and plans, and the drawings for the first section completed so that the first contract was advertised 6 months after the first report.


9' Sewer Brickwork
For detail of Gate and frame see Drawing
8'
Class 'A' Concrete
Reinforced with 3' Mesh Nº 6 Heavy Expanded Metal or Equivalent
Sewer Brickwork
6.0
9
Class 'P' Concrete
9
Section AA
Facing Mixture of 1 part portland cement 1 part sand 1½" thick
A
B
C
D
Existing Sewer
Existing Sewer
E
E
D
C
B
A

A Bell Mouth Connection.

The work was divided into sections of suitable magnitude, and three contracts have now been let, embracing a distance of about 3½ miles and representing an expenditure of about $400,000.



High Level Interceptor.

I have said very little about the provision for rainfall. This is a subject in itself, which to treat properly would occupy a great deal of time. I would merely remark in passing that it was proportioned according to formulae which are the results of many experiments by distinguished engineers. These formulae depend upon the slope of the ground, the proportion of impervious surface, the size of the districts, the character of the soil, and . . . personal equation.

I wish to pass lightly over the subject of specifications, merely touching on one or two of the more important items, which may be interesting to you.

Portland Cement is specified on the work under discussion, to be measured in such a way that a barrel of cement weighing 350 pounds net shall constitute a volume of 3.6 cubic feet. This assumption is empirical, but it is necessary to assume the volume of a barrel of cement, for it measures 25 per cent. more dumped loosely into a box than it does when in the original package.

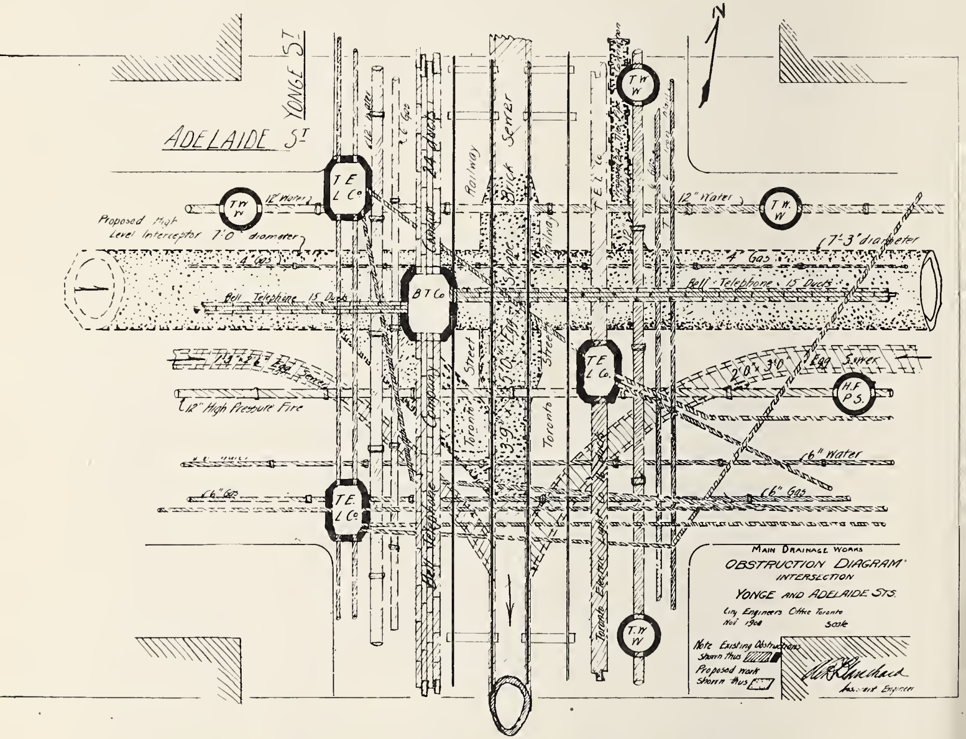
Frequently the barrel is assumed to hold 4 cubic feet, but the above assumption gives a slightly richer mix on the same proportions of aggregate.

The concrete used consists generally of a mixture of one part cement(measured as above), 3 parts sand and 5 parts broken stone or gravel (both measured loose), and water. The latter necessary ingredient, by the way, is frequently left out of specifications for concrete. In some cases where reinforcement is to be used, the mixture contains a larger proportion of cement. Excepting under special conditions there is no reinforcement in any part of the sewer, but where reinforcement is used the mixture contains a larger proportion of cement. All concrete is placed in the forms so wet that it would pour, and it does not require tamping. It is churned by a stick or steel fork, or hoe, to work up the air bubbles and work the finer particles to the face of the work. The old practice of using a mortar facing mixture has been abandoned entirely as it is not necessary in any way to secure a smooth finish. Concrete in open cut work is mixed by hand on a mixing board, placed directly over the sewer, and shoveled into tubes, which carry it to the work below.

The brick used is a hard burned wire cut shale brick, giving a satisfactory test for absorption and abrasion.

The construction work of the sewer under way is being done by two different methods. In the centre of the city where the sewer ranges in size from 6 feet to 7 feet 6 inches internal diameter, the work is being built in tunnel, and brick construction is being used throughout. East of this the sewer ranges in diameter from 7 feet 6 inches to 9 feet 6 inches, and is built of concrete with one course of hard burned brick, placed in the invert as a precaution against wearing. All of this eastern end is being excavated in open cut, and in these larger sizes the economy of the substitution of concrete for brick is very marked. The tunnel sections are being done by sinking shafts every three or four hundred feet and working headings each way from each shaft. By operating from two or more shafts the contractor is able to make the progress about what he wished. At the top of each shaft a steam hoist is rigged and the spoil raised and the construction materials lowered in buckets.

The excavation in open cut at present being executed, is being carried on by means of an excavating machine, which consists practically of a 2-drum hoisting engine (with traction attachment) which operates a scoop or bucket. The scoop is drawn forward in the trench by the heavier cable attached to the lower drum, and loads itself in travelling. The smaller cable attached to the upper drum passes over a sheave attached to the far end of the excavation and draws back the empty scoop for another operation. The process is continued and the scoop is dumped each time into a hopper above the street, from which cars or wagons standing on the street are loaded by gravity.



Obstruction Diagram—Corner Yonge and Adelaide Streets

A typical section of concrete sewer, with its invert lined with a single four-inch ring of brickwork is shown in Fig. 4. The construction of the circular manhole in concrete and the access provided by means of a ladder instead of the usual step irons are novel features in sewer work in this city.

In carrying out a work of this magnitude, the strictest attention is necessary on the part of the whole staff. The timbering of the trench and tunnel, the forms for concrete; in fact, each and every part of the work must be guided, arranged and inspected to the last detail. Copious notes must be kept; samples of the ground, records of old and fresh settlements of ground or buildings, regular progress profiles and photographs must be taken daily, or weekly. In fact, in the words so often quoted "Eternal Vigilance is the Price of Safety," and in such work as this through city streets close to valuable properties and buildings, the caution is doubly deserved.

No work now-a-days should be carried on without a cost record being kept by the engineer. A system of cost record has been devised to suit this particular work, thus: the work is primarily divided into sections. Each section is sub-divided and a separate cost amount is opened for each structural part, such as the sewer proper, each connection, syphon, or other sub-division.

Classes of work such as excavation, concrete mixing and placing, brickwork, etc., form further sub-divisions, and the records are kept on loose leaf cards. Materials are also kept track of in the same manner.

The design and construction of the work above described is being carried out in charge of the writer, under the general direction of Mr. C. H. Rust, City Engineer. Mr. W. Hollingworth is Resident Engineer in charge of construction, and the parties on the sections at present being constructed are in charge of University of Toronto men, Messrs. Percy Near and John McDougal.

THE ENGINEER AS A BUSINESS FACTOR.

EUGENE CREED.

It gives me much pleasure to take advantage of the invitation to address you, for I have "an axe to grind." No, I'm not going to offer something for sale; rather, I am here to advise you where a market for your brains may be found when you are ready to make a contract. I am in the electrical business, in the Central Station field. In this country and the United States there are 5,500 electric light and power companies who find it difficult to secure the services of men competent to market their product—electric current. To sell this commodity, we require men with engineering knowledge, and business or selling ability, and so we will discuss the "Engineer as a business factor." As I see it, an engineer cannot become a business man until he has learned to sell—in this instance electric current.

Mr. Louis A. Ferguson, lecturing on "Relationship between the Engineering and Commercial Departments" at the 31st Convention of the National Electric Light Association, said:

"The engineer must be of the highest, broadest type. He must have other qualifications than the ability to design the power house and calculate the sizes of the conducting wires and cables of the distribution system. He must have broad, sound judgment to determine the income value of any investment, of any extension or of any territory to be supplied. You may say at once this is not for the engineer to decide, but for the manager, or contract agent, or other commercial man, call him by any title you may choose. If we admit this, then we must acknowledge that there should be the most intimate relation between the engineering and commercial departments, and each should be thoroughly acquainted with the work of the other insofar as the return on the capital investment of the corporation is concerned. Unless this be so we may find a condition where the two departments are working at cross purposes, or, perhaps, through lack of proper knowledge, "saving at the spigot and wasting at the bunghole," the operating department struggling to bring down costs of production by scaling down a few tenths of cents per kilowatt hour while the commercial department is being outtraded in whole cents per kilowatt hour by the clever engineer of the purchaser or perhaps by the unscrupulous bluffer who takes advantage of the weakness of the contract agent who does not know the value of the product he is trying to sell.

"If the contract agent, or manager of the business getting department be a man trained as an engineer, either by education or practical experience, he is better able to handle the problems that confront him. Such training develops the analytical mind, increases the reasoning power, promotes sound judgment and teaches the man to differentiate between right and wrong. The man so trained does not do things by rule of thumb; he knows because he knows and acts upon his own knowledge, and does not follow blindly the lead given by others who may perhaps be mistaken in their conclusions.

"Such a man is not dependent upon others in his negotiations with the shrewd and clever business man, who perhaps is an experienced man of affairs and generally acquainted with some of the fundamentals of rate making; nor does he have to call for assistance when dealing with the consulting engineer or architect employed by the owner or purchaser with whom he is trying to do business. His knowledge that he is perfectly able to discuss intelligently with his customer the problem at hand in all its phases will give him a distinct advantage over the untrained man and will inspire in himself confidence in his own proposition and furnish the necessary courage to meet any argument or objection advanced by the purchaser.

"There is a tendency among some technically trained men, especially the younger set who have been out of college but a short time and whose minds have not sufficiently matured through wide contact with the world, to feel that they should not devote any of their time and thought and energy to the commercial side of the business in which they are engaged as engineers; that this is unprofessional and beneath their dignity.

"That this is a mistaken idea many of them realize in later years, when their success in life has not been as marked as some of their fellow men. They do not appreciate in time that all technically trained men cannot be great scientists and that there is a splendid field awaiting the use of their training if properly applied in the great market of commercial life."

Now, what is a sales engineer; what are his characteristics, and how does he differ from an ordinary engineer? Coming down Queen street one day last summer, I saw displayed in a store window a number of straw hats, at what seemed to be a very low price. Wanting a hat at the time, I dropped in, and the salesman who waited upon me tried about every hat in the store on my head, without finding a suitable fit. He played the gentleman all through; was not brusque, emboldened, or even suggestive. There was something taking and likeable about him, and I really was sorry I could not buy a hat—not because the hats did not fit me—but because I was anxious that the salesman should make a sale, because it pleases a salesman to sell goods if he is of the right mind and has enough rich red blood in his veins to feel a certain amount of pride in his work. Then I bought something I did not want, just because a qualified salesman was selling goods.

It is absolutely necessary that, if a man should rise in the engineering profession, to come out of the draughting room say where he spends eight or ten hours a day over a board, that he must have a certain knowledge of commercial engineering, as well as electrical, mechanical or civil engineering. It has been said that "Salesmen are born, not made." That is not so. A man learns to sell goods when he learns to read human nature. We see in the colums of the daily press, advertisements of so-called mind-readers, "second sight artists," as they are often called, and I am just superstitious enough to think that there is something in the knowledge these people possess, in that they have studied human nature—that the minds of the human family are divided into distinct groups, which they have analyzed. While it is true that no two members of the human family are just exactly alike, yet, we think very much alike in direct ratio to the society or environment in which we are placed.

I was connected with an electric company in the States which had secured the contract for changing from mechanical to electrical drive, the machine shops of a great prison, and it was my misfortune to remain in the Institution from 8 o'clock every morning until 5 o'clock at night, for about eight months, and I came very much in contact with the inmates. The prisoners in the shops where I was employed were all about the same type, seemingly, but they did not think along the same lines. They knew one about as much as the other, maybe, but before I had finished my work at the Institution I was able to judge whether or not an individual had been sent to the prison for larceny, robbery, murder, or some crime done in the heat of passion against the person, simply by sizing up the man from his actions.

It is just so in selling goods, whether you are selling electric motors, electric current for power, pumps, locomotives, or books. (I might suggest, in this connection, that if any of you intend to make commercial engineering your life work, that you get out during your vacations and take up the selling of books, maps, or any other article that will bring you into direct contact with the people.) You must be able to read human nature, and know the mind of your prospect.

Now, in the marketing of electric current, in which business I am engaged, we come in personal contact with all kinds and conditions of men; some of whom understand our explanations quite easily, others who are very dense. The electric company, as you know, must maintain very expensive machinery, lines, transformers, poles, etc., and must endeavor to sell its product as many hours out of the twenty-four as it possibly can. Its lighting business averages about three hours out of every twenty-four, but the machinery, etc., must be ready at any hour or any minute of those twenty-four to give this man or that firm as much light or power as he or they desire; that is, if the company is runing a twenty-four hour plant. The current cannot be stored, like gas. To make up for the twenty-one hours which our machinery is operating, for which we must employ men to operate, upon which there is a standing investment for depreciation, repairs, and losses of like character, we must endeavor to sell current for purposes other than light, so we look for power and heating business, but electricity is comparatively in its infancy, so we must educate the public and endeavor to sell the current to manufacturers for power purposes, so that we may be able to sell the light at reasonable figures, to the end that the majority of the people may take advantage of the benefits derived therefrom.

Now, only through the work of able, conscientious, painstaking, tactful, intelligent and likeable men, with engineering knowledge, is a corporation having this particular commodity to sell, best able to introduce its product, and afterwards hold its customers. A likeable man is he who impresses you as a pleasant, honest fellow, like the Queen street haberdashery salesman, who is careful never to violently disagree with you, and who, though he may be as intellectual as Bacon, as great a mathematician as Newton, or as brilliant an engineer as Steinmetz, carries himself as an ordinary individual who has the interests of his prospects at heart as well as those of his company. In approaching a prospect this likeable engineer states his business courteously, uses his keen knowledge of human nature in judging whether the prospect is in a mood to listen to the many virtues of electricity as an illuminant, a heating agent, or as a driving agent, and hear of its superiority over all other sources of light or power.

The salesman-engineer should necessarily have a very broad knowledge of engineering. You men who have had the opportunity presented of which you are taking advantage to secure a thorough training in the engineering arts in this University, are the men to whom the Public Service Company will look, for the purpose of educating the public to the many virtues of electricity.

It is undoubtedly true that no one appreciates the convenience and economy of electricity until he has tried it, and there are many who hesitate a long time before making a trial, and these are the people that the likeable salesman, with a knowledge of his business, must convince. After electricity has been used the price will gladly be paid, rather than go back to the old troubles of the mechanical drive, but it is necessary that we use a great deal of tact, common sense, and practical knowledge to convince the man that though his cost may be seemingly high, in the end he will increase his production by from 15 to 50 per cent.

It is also necessary that a selling engineer should have a knowledge of the competing lines. For instance, a young engineer from Brown University was soliciting for a central station company in Rhode Island. He had as a prospect the proprietor of a planing mill. Now the owner was a sharp old fellow. He had studied the rate question. When the subject of electricity was broached (the prospect, by the way, was using steam) the internal combustion engine manufacturers were on the job, and claimed that the cost per H.P. would be very low. The prospect told the salesman of the offer of the engine people. Knowledge of the cost of operating an internal combustion engine was necessary here, not the study of the human mind or knowledge of the psychology of the sale, but common sense and an acquaintance with the other fellow's proposition.

A pamphlet had been published on the subject of the internal combustion engine by scientific authorities, and at the time the reports were anything but flattering. Having carefully read this pamphlet, the trade papers and literature regarding costs of driving by various means, the engineer was able to call to the prospect's attention the very unsatisfactory report of the internal combustion motor. The engineer being the likable fellow we have mentioned, all the more impressive was the effect upon the prospect. An earnest, whole-souled, telling address, a forceful and logical way of stating the case, readiness to combat with arguments and to clinch his own with facts and figures, are essentials of the engineering salesman.

A sale must often be induced. They tell a story of a Baxter Street clothing merchant. He was teaching his son the methods of salesmanship, and he said: "Ikey, when a man comes in and wants to buy a coat and you sell him a coat, that is nothing, but when a man comes in and don't want to buy a coat and you sell him a coat, that is salesmanship."

So, for the benefit of you men who are about to graduate, or who will be graduated next year, who may be thrown into the maelstrom of active life, remember that if you go into the selling end of the game, you will often find it necessary to sell to men who, in their minds, have a coat that is good enough for them, and in the words of my friend Isaac Stein "do not want a coat."

Of course, in salesmanship, there is such a thing as going it too strong; being too conceited, having such wonderful knowledge of the goods that you will become more or less matter-of-fact in presenting your arguments, in having too much to say. The hot metal of enthusiasm, of course, is of great value to its fortunate possessor in entering a business career, but it must be tempered with the oil of judgment, in order to make a keen-cutting and effective weapon for its owner.

Some years ago a young shoe-salesman, so the story goes, brought in from the street a phlegmatic German jobber to look over his sample lines. The boss knew him and would ordinarily have taken a hand in the game, but, never having been able to do much with him, thought he would keep out and await developments. The enthusiastic salesman handed Mr. German a boot and gave him a full description at length of all its good qualities. As Mr. German laid it down another was handed him, and a third and a fourth, with similar long and gorgeous eulogies. Finally after saying little or nothing, Mr. German took his leave, and the manufacturer said as he passed him: "Well, I hope you left a good sample order, Mr. German." To which he replied, "Thunder, I didn't get no chance."

To quote Mr. Ferguson again: "This great country of ours is not a country where caste prevails, where to be respected one must be either a soldier or a professional man. Ours is, at the present at least, essentially a commercial country and its prosperity and prestige will continue in the future to be developed and maintained by the commercial engineer working in the industrial field.

"Why are the lawyers who have achieved marked success in their profession sometimes chosen to conduct the affairs of large undertakings? They are technical men. They are business engineers; they have been trained in the theory of what is right and wrong in business. Few lawyers of active temperaments would consider it beneath their dignity to give up a lucrative practice for the presidency of a large corporation or a great business. The same limitations which apply to the engineer as to his capability for the conduct of a large business apply similarly to the lawyer. He must be broadly educated either originally in his college life or in after years through contact with men of broad ideas and experience.

"The financier is a technical man; the expert accountant is a technical man—each in his own sphere. Neither would make good managers for large undertakings if they knew nothing of the technique of the other branches of their business or had not the special ability to direct men of technical training, or were not good judges of other men's ability.

"The development of our country is along the lines of concentration of effort. The crying need of our time is co-operation. Both of these are possible through the agency of corporations whose highest aim should be harmony and co-operation between the investing and the consuming public. Such harmony and co-operation must, however, begin within our ranks. In our business there is no greater immediate need or more far-reaching return than that resulting from the closest possible interchange of knowledge and the co-operation of effort between those departments having to do with the exploitation and physical development of our business."

Herbert Spencer briefly defined science as "organized knowledge." A recent writer said: "It is the knowing how to do a thing, and why it should be done in a certain way; it is the knowing and doing understandingly.

"Science, more than anything else, has contributed to the great advancement of the last century; science has in recent years entered into the conduct of business; it has brought about a complete re-organization, a new era has been born. Science has come to the assistance of necessity in the conservation of our natural resources. It directs intelligent attention to waste as a negative, and economy as a positive force in the upbuilding of mankind. In no field of endeavor has man profited so greatly as in the economies that have been effected in production and distribution. The public is given to-day many necessities at prices far below former costs of production because of the utilization of by-products heretofore wasted.

"In business, as in biology, it is a question of the survival of the fittest. Success is dependent upon preparedness, accomplishment and strength. In warfare it is dependent upon organization, efficiency, equipment, magnitude and capital. Success in business depends upon exactly the same conditions.

"Business is an occupation in which goods or services are exchanged. In the early stages of civilization things of value were traded or bartered. A day's labor was exchanged for shelter and food, or a bushel of corn for a quiver of arrows. It was soon found necessay to devise some suitable instrument to facilitate exchange. It should represent a standard of value. First beads or other crude articles and later precious metals were selected, and called money.

"The value of a thing, whether commodity or labor, is represented in price, or what it will bring in exchange for money.

"It was therefore seen that in order to dispose of labor, or a product of labor, it must be desired by another, and be worth to him the value represented by the medium of exchange, or its price in money.

"The basic principle in business then is to create something that will be of value to another, and to be able to produce it and exchange it readily for things that are of value to the producer.

"It soon followed that it was necessary to have two distinct departments to facilitate exchange—production and distribution. The occupation of some was in production, and of others in exchange or distribution.

"The value of a commodity is determined by its cost of production, plus its cost of distribution, provided its total cost does not reach a sum that will be in excess of what another will be willing to give for that particular thing, or for what it can be provided by another producer.

"The student in business to-day will therefore carefully study three things: The existing demand or a means to create or increase the demand, the cost of production, and the cost of distribution.

"The cost of production is determined by the cost of the materials, labor, and tools or machinery used in the process of production. The cost of distribution or selling is determined by the cost of labor, and other means of exchanging the commodity for money.

"In the great industries of the present time, the economic features are necessarily very complex, and it was only by giving careful study to all details connected with the two great departments of production and distribution that they were made possible.

"In the technical branches of business, skill of all kinds is required. The work of the designing and construction engineer is grounded on scientific principles. Raw material must be carefully selected and purchased at the lowest price obtainable for the quantity desired. The factories must employ skilled workmen, and use the most efficient and economical machinery in production. There are now many who make a specialty of consulting in factory management and economic production. Another very important branch of business is grounded on scientific principles—accounting. A manufacturing business to-day without the most modern system of accounting is as much a derelict as a rudderless ship at sea. The department of distribution is also to-day operated upon scientific principles.

"The selling of goods at a profit is a science. It requires a knowledge of the goods, an ability to persuade others that the goods are worth their value, to get orders and to hold customers.

"To do business resolves itself into the following factors: To produce something that is wanted, and others will continue to want; to know the true cost of production, and to keep the cost low enough so that with the cost of distribution and a fair profit added, the goods or commodity can be exchanged for money."

In conclusion: An engineer who chooses a commercial career must have a thorough knowledge of his profession, an intimate acquaintance with costs of production and distribution, and the ability to read the human mind and to do unto others as he would be done by.

COMMERCIAL TESTS ON TRANSFORMERS.

C. L. GULLEY, B. A. Sc.

It is the intention of the writer to give a few points regarding the testing of transformers by methods in use to-day by large manufacturing companies.

Commercial tests are tests made on machines which duplicate previous designs and their purpose is to prove correct manufacture. With the complete series of curves and records of tests which have been made on the first machine, it is an easy matter to check any detail of performance desired and to tell whether or not any particular machine of old design is up to the standard.

Transformers receiving full commercial tests are tested for resistance of high and low tension windings, for the polarity of these windings with respect to each other, for the ratio of the number of turns and therefore for voltage at no-load, for tap voltages, for losses i.e. core loss and impedance of the windings, for overheating and lastly for major and minor insulation.

For the measurement of resistances direct current is used, usually being supplied by a set of storage batteries, thus ensuring a steady supply. Direct current is used as pure "ohmic" resistances are sought. In addition to the resistances of the full high and low tension windings, the tap resistances are sometimes also measured.

The polarity of all transformers is determined for obvious reasons. This is done by making and breaking the circuit with a very small current flowing and noting the corresponding voltmeter kick.

The ratio of voltages of high and low tension windings is found by the two-voltmeter method. In the case where a high-tension transformer has a ratio such as 10:1, with a primary voltage of 23,000 volts and therefore a secondary voltage of 2,300, in all probability 1,000 volts or thereabouts would be impressed on the high-tension winding in order that the seconding induced voltage of 100 volts could be read directly on an ordinary voltmeter without inserting a step-down potential transformer. A 10:1 potential transformer would of course be inserted in the primary circuit, giving a reading of 100 volts on the voltmeter. In testing for ratio it is always advisable to exclude all potential transformers if possible as the ratio of the potential transformer itself is liable to be "off" enough to seriously affect the ratio of the transformer under test. Transformers with a ratio 1% higher or 1% lower than the rated ratio are rejected.

Three-phase transformers, where the independent phases are accessible, have the ratio of each individual phase measured, but others, such as Y connected machines where the neutral point is not brought out, require three-phase power, care being taken that the voltmeters across the high and low tension windings are measuring the respective voltages of the same phase.

In order to exclude voltmeter correction a similar set of readings are taken with voltmeters interchanged.

Complete ratio and polarity tests are required on one transformer of each group or "production order," the ratio and polarity of the others being determined at the same time by paralleling the tested transformer with one of the untested of the same group. The low tension windings (Fig. 1) in parallel receive full excitation (such a voltage generally being obtainable) thereby inducing full voltage in the high tension windings of each transformer which, as is seen by the diagram, are connected in series and are bucking each other. Then if the ratio and polarity of the two are identical there will be no current flowing in the high tension windings. If upon making and breaking the primary circuit a spark is observed, this unbalanced condition must be measured in either volts or amperes or both. It is always advisable to "try out" the connections at low voltage as reversed polarity in one transformer would cause a very disagreeable flash and would be liable to injure insulation.

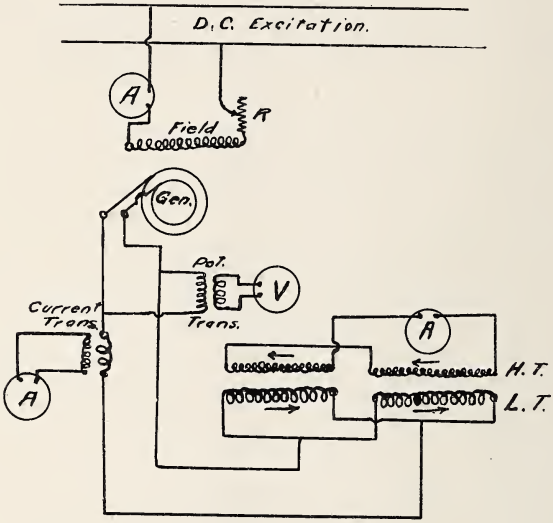


Fig 1. Connections for Paralleling Transformers.

Taps are usually located by the two-voltmeter method and must be correct to the nearest turn. If the high tension tap voltages are required the generator leads are connected across the full winding, the impressed voltage measured and at the same time the tap voltage is read. This method eliminates all error due to transformation.

The impedance of the windings must be carefully measured, due to the facts that transformers operating in multiple divide their load inversely as their impedance voltages, and that high impedance watts would mean excessive eddy current loss in the transformer. By impedance volts is meant that voltage which is required to force full load current through the windings with one short-circuited (Fig. 2). Impedance watts will usually not exceed 1% to 1.5% of the total capacity of the transformer. If the actual watt loss exceed that of the calculated by 15% at a given temperature the transformer is likely to be rejected. Great care must be taken to secure a low resistance short circuit. Ordinarily the normal point alone is taken, holding rated current and frequency, but on transformers of each new specification there is usually required a curve of impedance volts and watts at 50, 75, 100, 125 and 150 % of full load amperes. The temperatures of the windings are taken at the end of this test.

Core loss and exciting current are taken on all transformers at 75 and 100 % of normal volts. For this measurement the high tension winding is open-circuited and full voltage is impressed on the low tension windings at normal frequency. The low tension winding is chosen simply because normal high tension volts are usually unobtainable from the sources of supply. Volts, amperes, watts and cycles per second are read and temperature noted. On one transformer of each new specification a curve is required at 25, 50, 75, 100, 110, and 125 % normal volts. Connections are shown in Fig. 3.

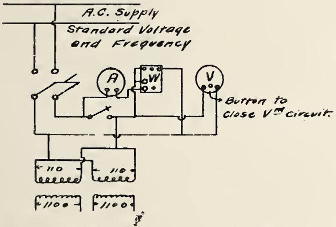


Figure 2— Core Loss Connections.

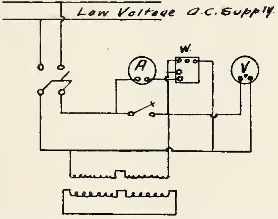


Figure 3. — Impedance Connections.

In measuring three-phase losses, either core loss or impedance, the two-wattmeter method is used, one set of instruments being transferred from phase to phase by means of switches. As this method is strictly correct only for balanced circuits, it is always advisable to "try out" the different phases and then read volts and watts across the two phases most nearly balanced. The true loss is, is you know, the algebraic sum of the two readings.

Three-phase, delta connected transformers should always have their delta circulating current measured and this should never exceed 15% of full load current. In some cases it is found to be zero.

In the following paragraphs the term "secondary" will be used to mean "low tension" and the term "primary" to mean "high tension."

Transformers are designed to run at full load with a certain temperature rise. A very common rise for designers on large transformers is 35° to 40° *C.* with a rise of 50° to 55° *C.* when overloaded 25%.

The heat run is ordinarily made on the maximum voltage connection. However, in some cases transformers will be designed for full capacity on all tap voltages, in which case there will be more than full load current in the winding, depending of course on the tap voltage used. In this case the cold resistance of the tap winding to be used during the heat run is measured, as the temperature rise of the copper is calculated, by the rise in the resistance of the windings thus, by the formula $T_h = (T_c + 238) \frac{R_h}{R_c} - 238$. For the rise in temperature the room temperature is subtracted from the above quantity. By holding the same current when taking hot resistances as that used for the cold resistance the above formula can be simplified to $T_h = (T_c + 238) \frac{V_h}{V_c} - 238$.

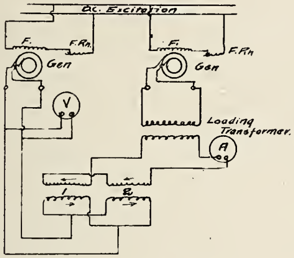
Transformers are connected up bucking or open delta and a current having a frequency of 24 cycles per second is applied to the high or low tension winding according to the loading transformer available. Here are a few of the available connections for single, and three-phase Δ and Y connected transformers.

The first case, the simplest, is that of two single-phase transformers connected bucking. (Fig. 4.) The secondaries are connected in multiple and excited, the generator supplying approximately twice the exciting current taken by one. The primaries and loading transformer are connected in series. From this arrangement all that will be needed to drive full load through the two transformers will be the impedance volts of the two which is supplied by the loading transformer connected to a generator. The generator supplying the loading transformer generates 2,300 volts so that unless the transformers under test are of very high voltage, the secondary of the loading transformer would be connected in series with the primaries of the transformer under test, *i.e.,* the loading transformer would be a step-down transformer.

Three similar single-phase transformers would be connected open and closed delta as is shown in Fig. 5. The principle is the same here. The primaries are in series through the loading transformer while the secondaries are excited closed delta.

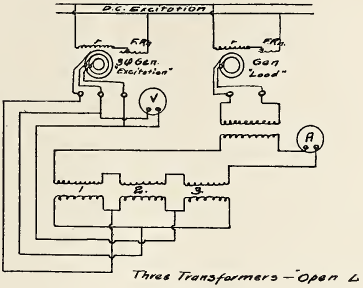
In some exceptional cases where the exciting current of three so connected would be too great for the generator available and where the primary voltage is obtainable, they would be connected in such a manner as to both excite and load the primaries. Here the exciting current of the transformers under test flows also through the winding of the loading transformer connected in series.

Four single-phase transformers would be connected after the manner of two, *i.e.*, the secondaries in parallel and the primaries in series, *i.e.* of course if the generators available were able to deliver four times the exciting current taken by one transformer. Three three-phase delta connected transformers with favorable conditions are connected with the secondaries closed delta and all in parallel while the primaries are connected all in series through the loading transformer.



Two Transformers — "Bucking."

Figure 4. Heating Test Connections



Three Transformers — "Open ∠

Figure 5. — Heating Test Connections

In all the above cases single-phase current is used to load both single and three-phase transformers. However, when a pair of three-phase *Y* connected are to be tested and there is no way of getting at both ends of the individual phases a three-phase loading transformer is used.

All heat runs are begun with hot oil or at an overload for the sake of saving time and power. In order to determine exactly what power is consumed by the transformers at normal load it is necessary to measure and record the core loss of the combination as wired ready for the heat run. Thermometers required on an oil-cooled heat run are: one in the oil of each transformer, one on the top and one on the bottom on the outside of the case of one transformer of a set and one to record room temperature. Of late it has been the custom to read the temperature of an idle unit that is in the neighborhood of the set under test. Variations in room temperature will affect a thermometer hung in the room far more quickly than they will a large transformer filled with oil and as the temperature changes of this idle unit will correspond to those of the set under test, due to variable air temperatures, these are taken in preference to the air thermometer readings. It has been found that the temperature rise has been above guarantee according to the air readings and whe ntaken above the temperature of the idle unit the rise has been within the guarantee. If the transformers are of the water-cooled type, thermometers are needed to record the temperatures of the ingoing and outgoing water.

The temperature of all terminals carrying more than 999 amperes should be measured at the end of the overload heat run and recorded. This is done to keep a check on any soldered terminals liable to be melted.

When an air-blast transformer is put on a heat run the screen is removed from the side of the transformer and thermometers placed on the iron and in the ducts, at the top and bottom. Two thermometers should be placed in each single-phase transformer, or in each phase of a three-phase transformer to record air escaping from the primary and secondary coils. The top damper. through which the air from the coils escapes, is not removed for the heat run but is put in normal running position in order to give correct results. For a 40° *C.* rise about 55 cubic feet of air per minute are necessary for each *K.W.* core loss and about 110 cubic feet per minute for each *K.W.* copper loss. For a 35° *C.* rise about 75 and 150 cubic feet respectively, are required. When the transformers are about up to the maximum temperature the thermometers should be moved around till the hottest place is found and care taken to keep them in the same position for the rest of the run. The air temperature should be taken in the chamber under the transformers. It is customary to heat up without air for one-half to three-quarters of an hour with normal load and 110% of normal voltage, being careful to note that the windings do not get too hot. Then with the air pressure specified, the coil damper is opened while the iron damper remains closed till the rise in temperature of the iron under the 110% voltage has reached the guarantee or has become about constant for a couple of readings. The voltage should then be cut down to normal and the iron damper opened. Resistance should be recorded each hour on the hottest primary winding and complete temperatures recorded. When four sets of constant readings have been obtained showing the temperature rises are under the guarantee on all parts, the overload run is started. For this the air pressure and position of the dampers remain the same. At the end of the overload, which generally lasts two hours, complete resistances of both primary and secondary windings should be taken and rises checked. Extreme care must be taken in measuring the hot secondary resistance since the contact resistance of a connector or interleaf terminal will often send the resistance and calculated temperatures up beyond all reason and make it necessary to repeat the run. If no overload is specified the transformers should be run twenty minutes at 150% load to test the soldered joints. When the heat run is off, air measurements should be taken on the coils and iron of each transformer with the air pressure and position of the dampers unaltered. When it is necessary to run a single transformer it gets the same test as above, but in two parts; first, on short circuit with air through the coils only, and second, on core loss connection, or open circuit, with air through the core only.

With water-cooled transformers they are heated up without water with 110% of normal voltage and the overload specified on the engineering notice until the oil temperature is 35° to 40° *C.*, or roughly till one-half of the guarantee rise is reached. Then normal voltage and current are applied and water turned on.

This water is adjusted till a 10° rise is obtained, *i.e.*, the temperature of the outgoing water is 10° higher than that of the ingoing and when several constant readings are obtained the overload is started.

High potential tests for major insulation are made between primary and secondary with secondary grounded to core, and then between secondary and primary with primary grounded to core, and occasionally between the phases of a polyphase transformer. The tank and core in all cases are of course grounded.

There are a number of different methods of applying high potential tests, but the one most commonly used is the spark gap method. (Fig. 6.) It is not absolutely reliable but with a little care yields fair results, especially at fairly high voltages. The Standardization Rules of the A. I. E. E. state with regard to the use of the spark gap: "The spark points should consist of new sewing needles supported axially at the ends of conductors which are each twice the length of the gap."

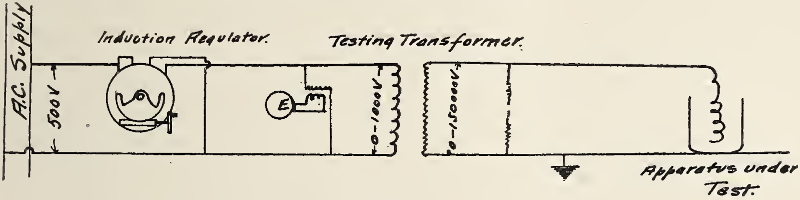


Fig. 6

To prevent a large rush of current and consequently high voltage surges when the gap breaks, there should be inserted a resistance of one-half ohm per volt in series with the gap's terminals. These resistances may be carbon resistance rods.

Moderately low voltages, say up to 30,000, require no particular care in application, except that they should be isolated so that no one will get hurt, and that their application should be fairly smooth. All voltages over 10,000 should be checked by a spark gap in the high tension circuit. Voltages, from 30,000 and up, require care in applying and removing them smoothly to exclude all surges. At voltages higher than 80,000, with apparatus of high electrostatic capacity, it is dangerous to break the gap at full test voltages, as the arcing gap sets up high voltage surges of the worst sort. The difficulty may be obviated as follows: The gap is set at two-thirds the required voltage, and broken with the transformer in circuit, the voltage being read just before the break. The voltage is reduced to zero and the gap opened 10% above the required testing voltage and the voltage applied till the voltmeter reading is three-halves its former reading, held for one minute, then gradually lowered to zero.

The induced voltage test for minor insulation, *i.e.*, insulation between turns and layers, consists of double the rated potential for one minute, followed by 150% potential for five minutes. One of the main objects of these tests is to find out if the high potential tests have injured the insulation between layers. They are made with 200 cycle power, thus cutting down the exciting current. When double voltage is applied to a transformer having any connection above 20,000 volts, a spark gap set 10% high with graphite resistances in series must be placed across either primary or secondary, and if this should arc over, the balance of the one minute test is held with a voltmeter reading lowered 11%. The exciting current is recorded in all cases. The transformer's primaries should be connected for maximum voltage and kept as far from each other and the ground as possible.

There is another insulation test—the measurement of insulation resistance. This is done roughly by a direct reading megohm meter. It is chiefly of value in determining the state of the insulation with regard to moisture, since the greater the degree of moisture the lower the insulation resistance. Any piece of apparatus showing low insulation resistance (5 meg ohms or less) should be carefully dried out before applying a high potential test of 50,000 volts or more.

Filling a transformer with oil is found to increase the dielectric strength of the insulation but the insulation resistance will be decreased. The oil from the bottom of the tank for a high potential test of 25,000 to 40,000 volts should have a dielectric strength of at least 20,000 volts for .2 inches; 40,000 to 60,000, a strength of 25,000 volts per .2 inches; 80,000 to 100,000, a strength of 35,000 volts per .2 inches; and all above 100,000 volts, 40,000 volts per .2 inches.

ROTATIVE DRY VACUUM PUMPS*

FRED. H. MOODY, B. A. Sc.

The vacuum pump as an important factor in the production of cheaper power, is receiving the attention of engineers in general at the present time to such an extent that a few words on the subject might not be amiss.

There are two distinct general classes of vacuum pumps —the wet and the dry. With the wet vacuum pump, everybody is more or less familiar, it being what is commonly called an air pump, used for maintaining a vacuum in condensers or other exhausted receptacles. In this form the valves are usually of the disc rubber lift type, sealed by the water passing through the condenser or apparatus to which the pump is attached, or else by water introduced for the sole purpose of sealing the valves and at the same time absorbing the heat of compression.

---

*This article gives the principal points of a paper delivered before the University of Toronto Electrical Club, November 8th, 1909.

It is not with this type but with the rotative dry vacuum pump, a comparatively recent development, that we will deal. In this class of pump, which uses no water in the cylinder or valves as in the wet process, the heat of compression is absorbed by a water jacketing system that completely envelopes cylinder, heads and passages. This brings out a very superior point in favor of the rotative dry vacuum pump, for, having no water to handle in the cylinder it can attain with safety high speeds; also, being rotative, tends to increase possible speeds as well as decreasing the clearance materially, due to a positive length of stroke. The latter features are not distinctive however, as the ordinary air pump is occasionally rotative.

There are numerous commercial uses for vacuum pumps, e.g., the exhaustion of vacuum pans and evaporative processes in sugar refineries in general, condensed milk plants, distilling plants, chemical and dye works, glue works, the manufacture of prepared foods, medicine, etc., preserving processes, the production of vacuum in central steam condensing systems and steam turbine work. Besides the above there are numerous special uses for vacuum pumps, two of which came under the writer's notice recently. One was the mechanical handling of safety razor blades by the Gillette Co. between the heating furnace and the oil bath; and the other, the rather prosaic matter of picking cranberries, both of which have proved quite successful.

In nearly all cases the dry pump has been the one preferred, for various reasons, the principal one being the higher vacuum possible. For steam condensing plants this is particularly desirable, the engine efficiency increasing considerably with increases of vacuum. As is well known the efficiency obtained by Carnot's cycle is the ideal sought by engineers, and is expressed by the following equation:

$$Eff. = \frac{T - T^1}{T + 461}$$

Where T is the absolute temperature Fahr. of the entering working fluid and T^1, of the outgoing working fluid—in a steam engine, the live steam and the exhaust steam respectively. At high vacuums, the temperature corresponding to the pressure varies quite rapidly for small pressure changes; and accordingly the Carnot's efficiency increases quite rapidly as the vacuum increases, particularly so at the very highest vacuums. As pointed out in a recent issue of Engineering, the actual efficiency of a reciprocating steam engine gets further away from Carnot's as the vacuum increases, while the reverse is true of the steam turbine. Thus, while there is a considerable increase in actual efficiency at high vacuums with the reciprocating engine, due to the increase in Carnot's efficiency being greater than the increasing discrepancy between the actual and Carnot's efficiencies, yet the increase is considerably more marked in turbine installations. It is for this reason that in the latter case, great attention is paid to high vacuums in the condensers. Rotative dry vacuum pumps as pointed out before, appear to be best adapted to this work. The General Electric Co. and Geo. F. Blake Mfg. Co. conjointly carried on a series of tests recently to ascertain the exact increase in efficiency in turbines due to high vacuums, but the writer has been unable to obtain the results of the tests.

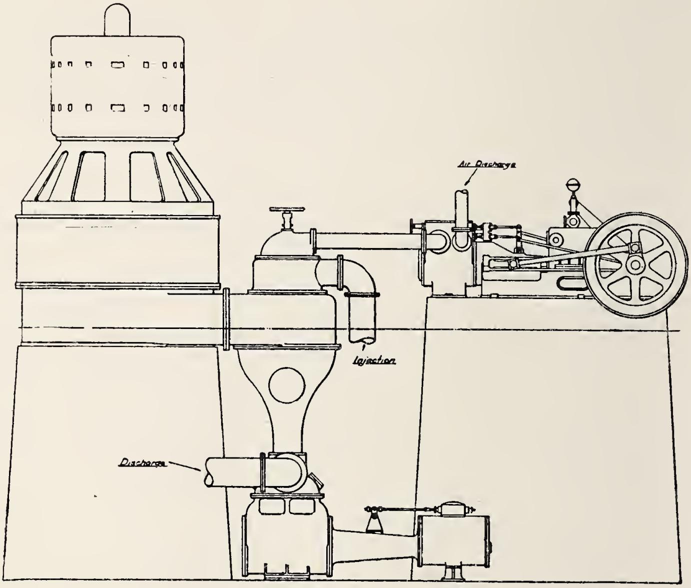


Fig. 1

Steam Turbine Installation using both wet and dry vacuum pumps

In condensers using rotative dry vacuum pumps an ordinary air pump is used in conjunction with the dry pump to merely handle the water. Fig. 1 shows such a turbine installation. In evaporative processes, higher vacuums do not cause much economy, as the total heat of evaporation decreases but slightly for the lower boiling temperature caused by increasing vacuum. The lower boiling temperature, however, is itself a desirable feature in many such processes, as for example, condensed milk.

Fig. 2 shows the cycle of operation, which in general appearance resembles a steam card. A positively operated slide valve of design to be considered later, opens the cylinder after the receding piston, which draws in the rarified vapour from the receptacle being exhausted, at the pressure in that receptacle. At the end of the stroke, the port is closed, and compression of the entrapped vapours commences. The other side of the piston, which at the end of the stroke is filled with vapour at the pressure of the discharge, is by-passed into the vacuum side of the cylinder, immediately after the suction port is closed, which nearly equalizes the pressures on each side of the piston.

This increases the pressure of the vapor being compressed. The line of compression follows a curve, which while not an isothermal in the strict sense due to leakages, which change the volume, is nevertheless nearly a constant temperature line, owing to the very efficient water-jacketing employed. At atmospheric pressure this compressed vapour is discharged by a valve on the back of the main valve before referred to. From there to the end of the stroke, the discharge continues. As previously mentioned, at the end of the stroke, the clearance volume vapour is equalized in pressure with the other side of the piston. The reason for so doing is quite apparent, a very high volumetric efficiency being thereby made possible, though to be exact a thermodynamic loss occurs due to expansion without any useful work being performed. If this equalizing of pressure had not occurred, but instead expansion had been allowed from the atmospheric pressure, it would have been impossible to ever reach the pressure of the vessel being exhausted on account of the clearance unless the stroke volume were much increased. For example consider the clearance volume to be 10 per cent. of the stroke volume (a conservative figure). As the expansion is nearly isothermal due to the water-jacketing, the pressure change would be inversely the volumetric change, which is 1 to 11, because PV is the equation of the isothermal. This would mean a final pressure of 2½" of mercury. As 1" and below are common vacuums, this method cannot be employed, for even if the clearance volume were decreased enough to give more than the necessary pressure range, the volumetric efficiency would be so small that a much larger machine to do the same work would be required. The thermodynamic loss is thus compensated for by the mechanical gain. With the method employed volumetric efficiencies as high as 96 per cent. are obtainable. Right after the end of the stroke, the by-pass is closed and immediately thereafter the suction passage is opened, and a fresh charge drawn in, this cycle continuing indefinitely. The card shown is from an actual pump and shows diagrams for both ends

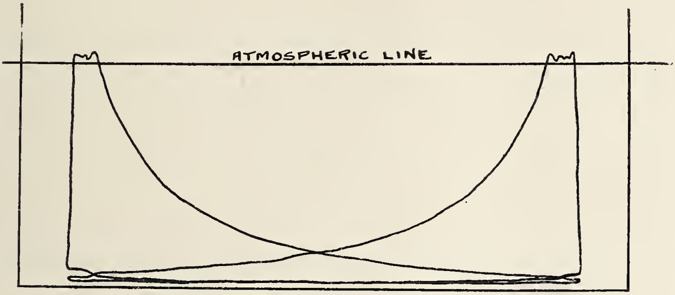


Fig. 2

Cycle of operation of an R.D.Y. pump for both ends of the cylinder

The matter of design to fulfil certain conditions cannot be treated very fully theoretically, experience having proved best. An approximation can be arrived at, however, introducing certain experimental factors. Take as an example a vacuum pan in a sugar refinery. The amount of vapour (i.e. its volume) given off at a certain vacuum, is known. Theoretically, twice the stroke volume by the speed is equal to this volume of vapour. But there is a loss due to the volumetric efficiency being less than unity, and also from the fact that leakages occur between the high and low pressure sides of the piston, and also at the gland, which increase the volume to be handled. To take care of these losses, experimental factors have to be introduced which increase the size of the machine from 25 to 40 per cent., depending on the capacity of the machine. As a machine under different conditions will not act the same, the operation of the machine is made flexible to take care of this, it being designed to operate equally well considerably above or below 150 r.p.m., which is considered to be the best speed for most purposes. This flexibility requires a heavy fly wheel and a governor that may be adjusted. For the latter, a veriable spring throttling governor appears to fulfil the conditions excellently as it may be readily adjusted.

Fig 3 shows the latest type of R.D.V. pump built by the Geo. F. Blake Mfg. Co. In general it can be seen that the cylinder and passages are identical with a slide valve steam engine, except that every part is water jacketed. In determining the size of the passages, a mean velocity of 5,000 feet per minute of the rarified vapour is adapted, practice having shown that to be reasonable. This considered with the size of the cylinder and usual speed of 150 r.p.m., gives the passage area. An excellent water jacketing scheme is employed whereby every part of the

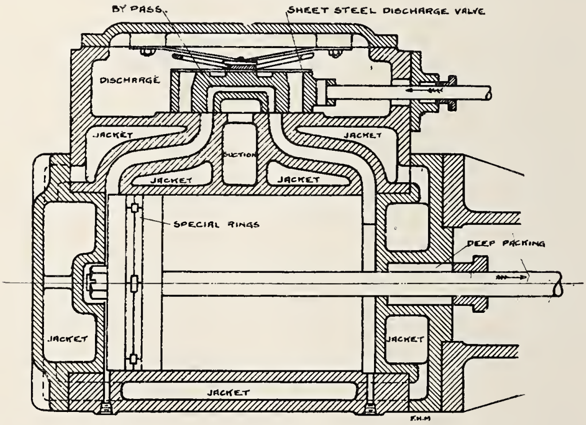


Fig. 3

Cross section of latest construction of R.D.Y. pump with L.Y. valve cylinder, heads, and passages is surrounded by cooling water. The reason of this might not seem apparent at first, but when we remember that vapour at ½″ pressure and 60° F., increases over 1000° F. when compressed adiabatically to atmospheric pressure, we see that considerable heat is generated. In the R.D.V. pump, the heat generated would not be so intense owing to the by-pass vapour and leakage. With the complete water jacketing there is practically no increase in temperature.

Various types of valves essentially the same as that shown in Fig. 3 have been used until the present LV type shown in that figure is now used exclusively in all Blake pumps. The valve is essentially an ordinary D slide valve with a by-pass passage through the bridge between ends and the ends themselves extended as in the main valve of the Meyer steam valve. The valve operates much as an inside admission D slide valve, suction entering through the centre cavity, and discharging into the two end spaces. From these two end spaces the air is let out by a sheet of Vanadium steel on the back of the main valve, and which opens with the slightest increase of pressure on the inside over that on the outside. This is simple and has proved quite efficient. The by-pass is wide open at both ends when crank is on dead centre, i.e., the valve is on its centre position for crank dead centres.

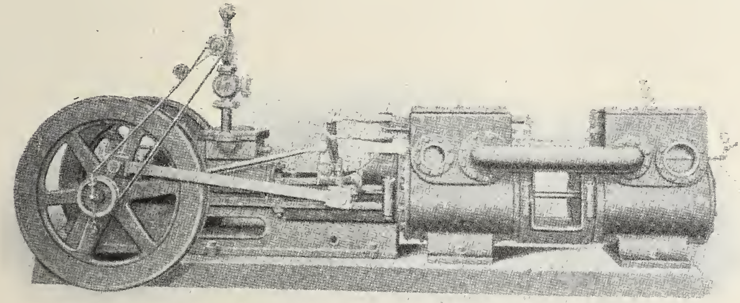


Fig. 4

6x12x12x12 Two-stage straight line R.D.Y. pump for extra high vacuum work (old style air valve gear shown)

One of the vital parts of the pump is the piston, for much of the leakage occurs there and as previously pointed out a small leakage to the suction side decreases the amount of fresh vapour that can be handled per stroke. A special piston ring is utilized. This consists of the usual uniform thickness piston ring, cut into an even number of pieces, from 6 to 8 inches long, with T-shaped pieces fitted into circumferential grooves. Pressing radially outward on these T pieces are coiled springs, which maintain a uniform pressure of the rings against the cylinder walls.

As it is impossible to completely eliminate all leakages passed the piston, another plan has been adapted for extra high vacuum work, such as exhausting lamp bulbs. This method consists in reducing the maximum pressure differences on the two sides of the piston by making the process two staged. Two cylinders are arranged tandem, each similar to a single stage machine as shown by Fig. 4. The first takes the rarified vapour from the receptacle being exhausted and discharges into the second, which in turn discharges into the atmosphere. Vacuums within 0.1" of the barometer are possible by these means. All the large lamp companies use this type for bulb work, for high vacuums are particularly desirable there, adding materially to the lamp life.

Dealing with the R.D.V. pump as a machine, there are two general types, the straight line and the crank, the latter being sub-divided into inside and outside. The crank type is similar to an ordinary steam engine having the vacuum cylinder attached behind the steam cylinder. The straight line (Fig. 4) is unusual and is worthy of note, as it is a general favorite, being remarkably compact. As shown, the steam and vacuum cylinders are directly connected, with an arm crosshead attached to the piston rod between the two. The flywheel shaft is in bearings immediately forward of the steam cylinder with the steam gear between the bearings and flywheels outside with crank pins in the latter. Two connecting-rods attach crank pins with the cross-head.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF
TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 JANUARY, 1910 New Series Vol. 3, No. 3

MODERN METHODS OF SEWAGE DISPOSAL.*

By T. Aird Murray, M.Can.Soc. C.E., Toronto.

Consulting Sanitary Engineer to the Saskatchewan Government.

The short time at my disposal this afternoon will only allow of a few casual remarks upon a subject which could only be dealt with fully and intelligently in a course of several lectures.

Recent research work and the published reports of the findings of several commissions in Europe and the States, enable one to classify data on the subject of Sewage Disposal; and, further, to crystallize certain defined deductions. It will be my endeavor to-day to attempt to put before you what I understand to be the deductions which can be drawn, based upon present knowledge. I will first address a few general remarks to you, and then throw on the sheet views illustrating several of my points, and the various parts which make up a modern sewage disposal plant.

What exactly is this question of sewage disposal?

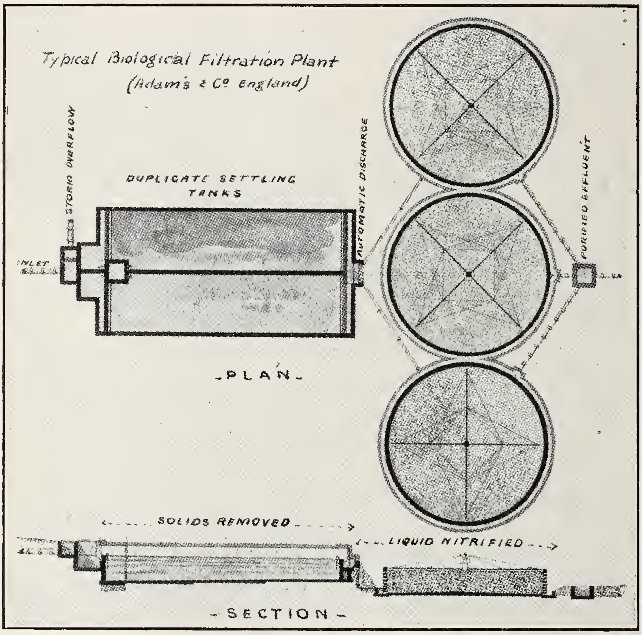
We find throughout parts of Europe, especially in Great Britain, and the United States of America, huge sums of money have been, and are now being spent, not only in investigation work, but in installing a variety of plants, some more or less successful. The problem, experimental and otherwise, has been before the greater part of the civilized world for over forty years and is now in a practical form before the people of this country.

The term "Sewage Disposal" has by custom come to mean some applied method of dealing with sewage, so that little or no nuisance will result from its ultimate discharge. Sewage Disposal is the product of the "Water Carriage System" of sewage drainage. Before the "Water Carriage System" came into vogue, what we then understood as sewage was dealt with by the "dry pail" or some such system of collection. Now, however, with the adoption of the "water carriage system" sewage may be defined as simply the water supply of a community after it has been used for a multitude of cleansing purposes. In short the water supply after it is contaminated and mixed with the bulk of human and trade waste which it is necessary to discard daily.

---

*Paper read before Engineering Society, Nov., 1909.

The necessity of sewage disposal is the direct result of the acknowledgement of a communal responsibility or duty. It is necessary that a community borrow from nature's supply a quantity of clear water, it cannot destroy or use up this water, but must eventually return it to nature. If, before returning the borrowed water, no reasonable method is adopted of removing the greater part of the impurities gathered by contact with a community, it has been found that the sum total supply of water in any country deteriorates and the general community suffer. Hence the question of the prevention of the pollution of streams and waters generally, has been recognized by national and state restrictive laws.



A Modern Sewage Plant

Sewage, or discarded water supply, if untreated by any method of sewage disposal, may either be left to soak into the ground in the vicinity of buildings, and, as often happens, near wells; or it may be carried to some distance by underground channels or pipes, and discharged into some natural drainage source, such as a stream or lake. In all cases, however, it must go somewhere, and carry with it all the collected town filth, until such filth rots out of organic existence, either in the interstices of the earth, is oxidized in a running stream or lost by dilution in some large body of water. That all this filth is eventually changed into harmless products by nature itself, no doubt exists. But the point is, shall we allow this rot and decay of organic filth to take place in our open streams or in the earth supplying ground air to our dwellings, or shall we confine the graveyard to some particular location where the process of oxidation rendering the organic matter stable may be accomplished under direction and supervision, and to the avoidance of any general nuisance to the community. It is admitted on every hand that the filth contained in sewage is not only a danger to the community directly producing it, but also to any community which may come into contact with the eventual discharge.

Now what can we really do with this sewage in order to render it practically harmless and confine the process of purification within a ringed fence.

Nozzle Spray Filter Bed at Hamilton, Ont.

First: What is this sewage? Most of you may have observed it as it empties from an outlet sewer into a stream or other location of discharge. As far as appearance goes it just looks like grey dirty wash water, with occasional floating solids of excrement, paper, corks, orange peel, etc. If the sewer is a short one, with a good gradient, there will be a large amount of these solids apparent. On the other hand, if the sewer is a long one with flat gradients, a very small amount of solids will be observed, as in the latter case they will be broken up and mixed with the liquid, or have undergone a certain amount of decay or rot during the period retained in the sewers. In fact, in modern sewage disposal language, the sewage will have undergone septic action in the sewers previous to discharge. In either case, however, whether the sewage is fresh delivered or is in a semi-rotten state of putrefaction, the apparent grosser solids can easily be removed by simple straining. All that is required is a small chamber provided with vertical gratings which will keep back the grosser solids and only allow the dirty grey looking water to discharge.

This operation of retaining the solids by means of a mesh strainer is the first or primary process in all sewage disposal plants, no matter what the ultimate method of purification may be.

When an analysis of crude sewage is presented it generally refers only to the dirty grey liquid minus the grosser solids.

Now let us suppose that this glass of water which I have in my hand represents the dirty grey liquid after the grosser solids have been removed by straining.

If this sample of average domestic sewage is from a water closet town with a per capita water supply of about 35 gallons per day, an analyst would probably tell us that it contained about 40 parts per 100,000 of suspended solids of which about half was organic and the other half mineral, about 80 to 100 parts per 100,000 of solids in solution, about 4 parts of ammoniacal nitrogen, and that it was capable of absorbing from 10 to 12 parts of oxygen in about 4 hours. In fact, that the glass of liquid was almost a breathing thing, absorbing oxygen and eliminating carbon dioxide. He would further tell us that an ordinary thimble filled with the liquid would produce colonies of bacteria anywhere in number around a figure of 5,000,000.

Now if we let this glass of dirty grey water stand for an hour or two, a thin layer of sediment will form on the base of the glass. This sediment represents approximately from 70 to 80 per cent. of the suspended solids which the analyst has defined. The reason why this sediment has formed is that so much of the solids is heavier than water. Part of the solids will be found to rise to the surface because they are lighter, and part will remain in the body of the liquid because their specific gravity is so near that of water. Now no matter how much longer we allow this glass of liquid to stand, no greater amount of suspended solids will settle out, unless we add to the liquid some re-agent, precipitant or coagulant. Even then the whole of the suspended solids will not be removed. The water will still remain dirty and grey looking.

The above process is, generally, the second one in sewage disposal. It follows straining, and precedes any attempt at purification in the sense of chemical change. The process is called "sedimentation."

Both straining and sedimentation may be said in a sense to purify the sewage, inasmuch as the resultant from both processes is weaker in organic matter than the crude sewage. With the retention and settlement of the solids much organic matter is removed and great numbers of bacteria extracted from the liquid. As sludge, however, the solids still remain to be dealt with. They must be either dried, burnt, buried, or allowed to remain and rot away by septic fermentation. It is in the latter sense that the septic tank comes into action. The ordinary sedimentation tank is transformed into what is called a septic tank, by allowing this settled sediment to accumulate and rot, with the object of its total elimination. It is now, however, being recognized that the adoption of this process has objectionable features. Only about 25 per cent. of the settled solids are so eliminated, and further the liquid sewage constantly passing over a fermenting plane of putrefying sludge gathers up the sludge into itself, and consequently in time the amount of solids in the liquid effluent from the tank is about equal to the amount in the influent sewage.

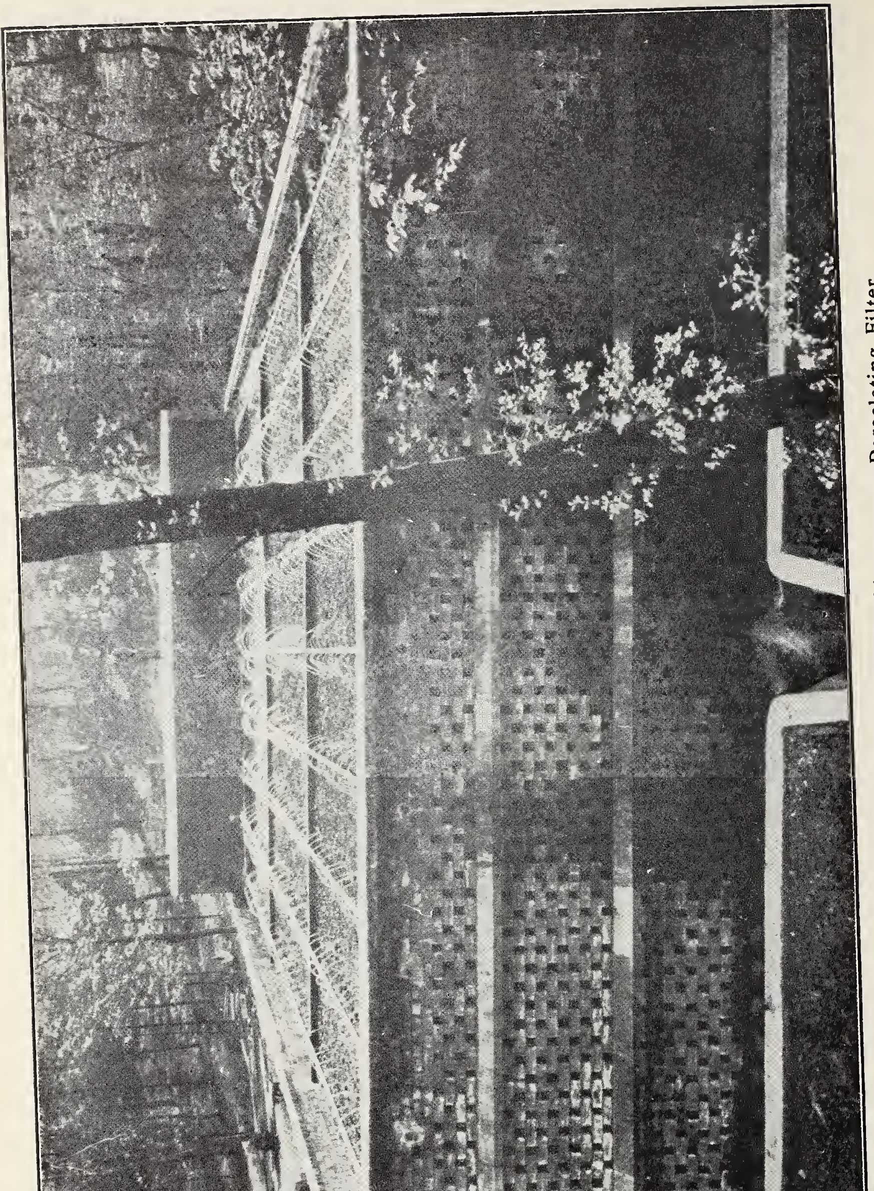
Modern methods for removal of solids mostly include some device for the removal of the settled solids as quickly as possible from contact with the liquid sewage.

It is really only the dirty grey liquid that we require with not more than about 20 to 30 per cent. of the total solids remaining in it, and we should have this liquid as fresh as possible, and not depleted of any of the available oxygen it may contain.

The main point, however, which I wish to lay stress upon is that septic action was never intended as a means of purifying sewage, but simply as a means of getting rid of the sludge difficulty. To many the term "septic tank" stands for sewage purification. It means nothing of the kind.

So much then for what can be done by straining and sedimentation. We will, further, now suppose that we have decanted the grey dirty liquid and left the sediment behind. If we pass this liquid through a layer of filter paper, the first passage will make little or no appreciable difference to turbidity, but if we repeat the process several times, the liquid becomes quite clear. It has all the appearance of ordinary water, loses its dirty grey color, and, in fact, looks drinkable. All the suspended solids, or practically all, have now been removed. This process is called "mechanical filtration," or in sewage disposal language, "clarification." In the sense of removal, but not of purification as far as any chemical change to the organic matter is concerned, the sewage will now on analysis prove weaker in organic strength. A further percentage reduction of bacteria has been effected; in fact, all the bacteria which were contained in the solids have been removed by passage through the filter paper.

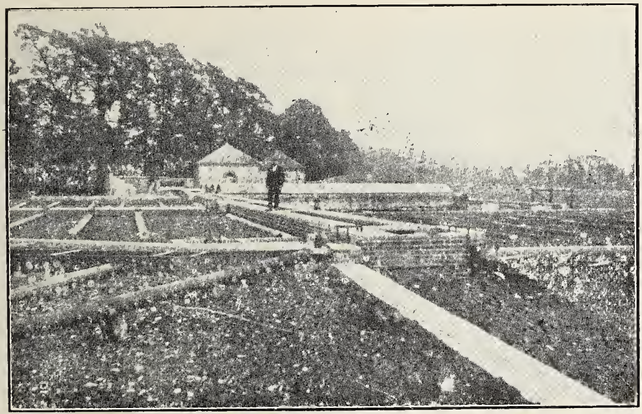
We have now a glass of apparently clear water. Now this glass of water which represents a product after straining, settlement, and mechanical filtration is still in every sense of the term sewage. Let us re-submit this clarified liquid to an analyst, he will have no difficulty in pronouncing it to be sewage. He will tell you that it contains bacteria to the number of somewhere over 100,000 per cubic centimetre, that a large proportion of the



Fixed Pipe Sprays Distributing Sewage Liquor over Percolating Filter bacteria are peculiar to the intestines of animals; that it contains a large amount of organic matter in solution; that it is capable of absorbing about from 7 to 8 parts per 100,000 of oxygen in 4 hours, in fact that it is a fair sample of sewage minus solids in suspension.

We do not require, however, to go to the analyst to find out that there is something radically wrong with this apparently clear water. If we let the glass stand for a time the water will again become turbid, and thread-like film growths will appear. It will undergo putrefaction by the decomposition of the organic matter in solution. If allowed to stand long enough, the analyst could no longer pronounce it sewage, but might say it was polluted with sewage, because he finds the products of decomposed organic matter present. To render a sewage effluent stable by oxidation is called "The Removal of Putrescibility."

A great deal of study has been given to, and a great deal written about "The Removal of Putrescibility," which in ordinary language means the purification of sewage in an accepted sense. Suffice it to say, that this process of fermentation by which organic matter is rendered partly inorganic is called "Nitrification" because the organic nitrogen is first changed by fermentation into nitrous acid, and then oxidized into nitrites, and nitrites into nitrates (by the nitrifying bacteria).



First Contact Beds, Sutton Surrey, England

The practical question in sewage disposal is, shall this process of oxidation or removal of putrescibility be allowed to take place as putrefaction in our streams and creeks, with all its attendant nuisance from smells, discoloration of water, and danger to health, or shall we take the matter in hand and see to it that the sewage is rendered non-putrescible before allowing it to run free.

If we determine to take the work in hand, we will find that the natural soil, granted plenty of it, of an open and friable nature, is the best and most efficient machine for the purpose. However, suitable land is difficult to obtain, and usually it is not sufficiently porous to allow of both liquid retention and air retention necessary to oxidation or nitrification. Further, in Canada one might just as well discharge sewage onto a concrete surface as on to soil in winter time, and nitrification ceases during frost.

A mechanical filter, however, can be constructed which will not only act as a strainer such as the filter paper, but will act also as a nitrifying medium. The question is mainly one of choosing a filtering material which will provide both water retention capacity and air capacity at the same time, so that every drop of sewage as it passes slowly through the filter will be in constant contact with oxygen. Any material such as soil used as a sewage filter is de-aerated and becomes what is called sewage sick, allowing an accumulation of organic matter which is retained unoxidized, and only subject to anaerobic decomposition.

The method of depending on a more ideal filtering material than soil has come into general use and has been named "Biological Filtration" although it is no more biological than any other process for the removal of putrescibility where fermentative nitrification is the reductive factor.

The process is entirely suited to a cold climate, because the works or filter take up very little room, and can be controlled in cold weather by coverngs or heat provision. To put the question of area in a nutshell, a population of 24,000 with a water consumption of 60 gallons per head per day would require an area from 76 to 288 acres of land for soil treatment, while only .88 of an acre in area of filter 6 feet deep would be required for biological treatment.

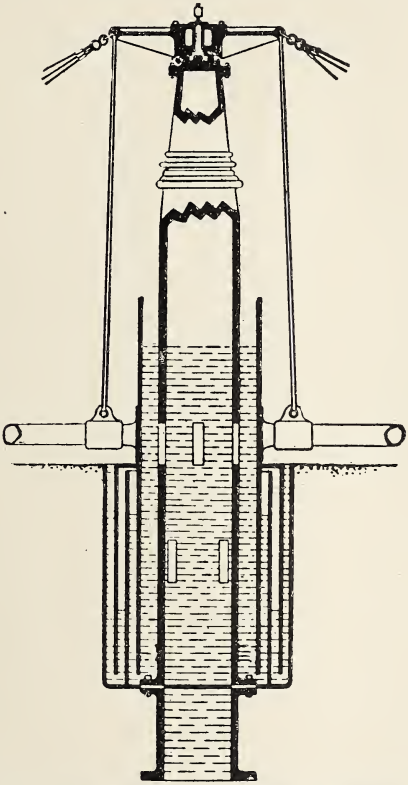
Apart from the question of frost, there are other reasons which appear to favor the installation of filters of a mechanical type. Even with the very best of land there are many cases of failure, although for the first few years good effluents may be produced. Examples exist in the State of Massachusetts where intermittent land filtration gave high efficiencies at first with a gradual falling off as the land became sewage sick.

The efficiency of a biological filter depends greatly on the method adopted of distributing the sewage over the surface area. Illustrations will be shown you of two of the principal methods employed, namely by the use of fixed sprays and revolving sprinklers. Fixed sprays as adopted at Columbus, Ohio, and other places in the States, as well as at a few plants in Great Britain cannot be said to be a success. This method of distribution does not in practice provide equal distribution of the sewage over the surface, in fact, parts of the filter bed receive as much as ten times the sewage as other parts, while only about

60 per cent. of the bed is wetted at any time. The concensus of opinion appears to be in favor of some form of revolving distributor, an illustration of which is produced.

These distributors of the revolving type can be made to work by power derived from the sewage itself, by collecting the sewage in a small dosing tank fixed about 18 inches above the level of the filter bed and feeding the sewage intermittently by aid of a syphon.

Biological filter plants have been constructed on two systems. The one "the contact system," and the other the "continuous percolating system." The percolating system is in every sense superior to the contact system, as with the latter air is excluded for a time from the filter-bed, and the filters become anaerobic or simply septic tanks. With the former air being always present, an equilibrium as between retention of organic matter and oxidation can be maintained resulting in continuous nitrification.



Revolving Distributor (Adam's Crescent)

To recapitulate we have divided sewage disposal into three stages, viz.:—

(a) Straining out the grosser solids.

(b) Retaining a proportion of solids by sedimentation.

(c) Rendering the liquid from (b) non-putrescible by mechanical filtration combined with a process of oxidation.

What about the non-putrescible effluent resulting from (c) process? Is this drinking water, or even fit to mix with a drinking water? By no means; what has been done is all that at the present time is generally asked of any community. The sewage in the chemical sense of the term is stable, resulting odors and general nuisance have been eliminated. What has been done is to render it possible for any community to use a water, receiving the sewage effluent, as a source of water supply, provided that the water is treated by slow sand filtration, or by some other water purification process.

Purification of sewage cannot be said to be complete unless disinfection is adopted as the fourth or final process. That disinfection is a practical method of dealing with sewage has been clearly demonstrated by valuable experiments carried out in the United States, the results of which have only recently been published.

Sterilization or disinfection, however, cannot economically be viewed as a substitute for any of the processes (a), (b), and (c), but only as an adjunct or fourth process. It appears necessary in order to economically and efficiently sterilize a sewage effluent, that most of the suspended matter be removed and that the liquor be rendered non-putrescible by preliminary treatment.

Just how far it is necessary to adopt all of the above processes in one combined sewage disposal plant, depends entirely on what are the particular conditions to be dealt with. The character and size of the body of water receiving the effluent will generally prove the ruling factor in determining the amount of purification required. Cases will occur where simple straining or straining and sedimentation may be sufficient, or in extreme cases it may be necessary to even go as far as disinfection. In the majority of cases, however, it will be found that the discharge of an effluent rendered non-putrescible will meet ordinary conditions and requirements.

The purity of river water is not only affected by sewage effluents, but contamination may arise, and does arise from a variety of causes, especially from unit discharges, which it is generally difficult to control. River water should always be treated by some method of purification before being used as a domestic water supply. It does not, therefore, appear necessary to duplicate final treatment, but it does appear right and fair that a community sufficiently purify a sewage effluent to an extent, which makes final treatment of a water supply a practical possibility.

I regret that the short time at my disposal has only allowed me to casually skim over a large and most interesting problem. The whole subject of the removal of putrescibility in its chemical and biological features is like a tale from fairyland, and certainly deals with a world which is not in an ordinary sense in evidence. The chemist and the bacteriologist are now giving acute attention to the subject of sewage disposal. I will, with your permission, bring these few remarks to a close by advising any of you who intend to take up this special feature of engineering work to make yourself well acquainted with the sciences of organic and inorganic chemistry, and of bacteriology.

A NEW MOMENT TABLE.

C. R. YOUNG, B.A.Sc., A.M. CAN. SOC. C.E.

The analytical determination of shearing forces and bending moments in girders and trusses due to moving locomotive and train loads has been much facilitated by the use of moment tables, but with the tables in general use it is still necessary to perform considerable calculation in obtaining the live load stresses in a structure, especially for those cases where a portion of the uniform train load is on the span.

Thus, referring to the commonly specified live loading for railway bridges, two conventional consolidation locomotives coupled together and followed by a uniform train load, the moments commonly listed are only those about successive wheels for all the loads to the left of each wheel and these moments are carried only to the beginning of the uniform load. Since the right-hand support of the girder or truss generally falls in between two wheels or somewhere along the uniform load, increments have to be added to the quantities listed in the ordinary moment table to give the moment about the right support. Where no uniform load is on the span, the desired moment is obtained by taking from such a table the moment of all the wheels to the left of the first wheel from the right support about that wheel (see Fig. 1) and increasing it by the total load on the span multiplied by the distance between the right support and the first wheel from that support. If a portion of the uniform load is on the span as in Fig. 2, the moment about the right support is found by taking from a table of the usual form, the moment of all the wheels on the span about the beginning of the uniform load and increasing it by the sum of the wheel loads on the span multiplied by the distance between the beginning of the uniform load and the right support and also by the moment about the right support of the portion of the uniform load on the span. The calculation of these increments again and again involves a loss of time which may be obviated by the use of a sufficiently comprehensive moment table.

With the object of thus shortening calculations for shear and moment due to moving locomotive and train loads the accompanying table, Fig. 3, in which the moments are given about successive points one foot apart, is herewith submitted. The loading chosen is one used extensively in Canada, Class 1, Dominion Government Specifications, 1908. Moments for other classes may be derived from the table by multiplying the quantities given therein by the ratio of the uniform train load of the class under consideration to that of Class 1. Similar tables may be readily computed for the loadings of other specifications.

In preparing the table special care has been taken to arrange the quantities given in the most convenient manner for easy and rapid reading of results. Above the wheels are given the distances between wheels in feet and the loads for one rail, in thousands of pounds, or kips. Below the wheels are given the distances in feet from the first wheel of points one foot apart up to 209 feet, the sum of the loads from the left up to and including the wheel load under consideration and the moment of all loads to the left of, and about, points one foot apart, up to 209 feet from the first wheel. Lines connecting these quantities to the proper points on the base line facilitate the reading of the results from the table while the use of especially heavy lines at the wheels and at points ten feet apart along the uniform load serves to mark the table off into divisions, thus making the location of a given point easier than if lines were all of the same weight. Staggering of the quantities, contributes to the legibility by reason of the large size which can thus be given to the figures. One hundred feet of uniform load is included in the table in order to make it applicable for maximum reaction calculations to all spans up to 200 feet.

The amount of shortening of computation effected by the use of the new table over the less extensive one can be seen best by considering some typical examples.

Let it be required to find the live-load shear at the quarter-point in a girder of 72-foot span with wheel 2 of the loading for which the table is prepared at the point (Fig. 1). Assuming that the table contained only the moments about successive wheels of the loading, the shear, V, at the point being equal to the left-hand reaction minus load 1, is found thus:

$$V = \frac{5508.0 + 182.7 \times 6}{72} - 12.15$$

$$= 79.575 \text{ kips.}$$

With the table as prepared in Fig. 3, the calculation would be:

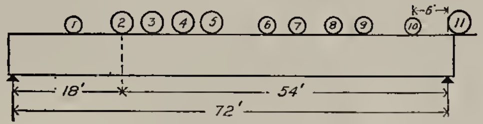


FIG. 1

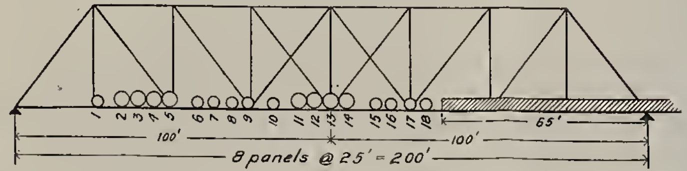


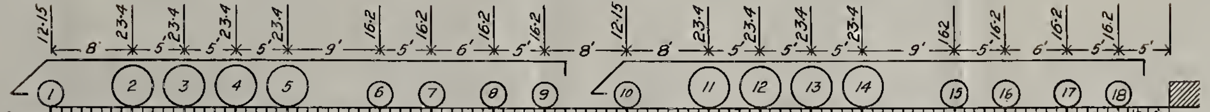
FIG. 2

MOMENT TABLE

FOR **ONE** RAIL

CLASS I LOADING, DOMINION GOVERNMENT SPECIFICATIONS, 1908

Loads in kips. Distances in feet. Moments in kip-feet.



Distances from first wheel	Sum of loads	Moments of all loads to left
0	12·15	0
1		12·15
2		24·30
3		36·45
4		48·60
5		60·75
6		72·90
7		85·05
8	35·55	97·20
9		132·75
10		168·30
11		203·85
12		239·40
13	58·95	274·95
14		333·90
15		392·85
16		451·80
17		510·75
18	82·35	569·70
19		652·05
20		734·40
21		816·75
22		899·10
23	105·75	981·45
24		1087·20
25		1192·95
26		1298·70
27		1404·45
28		1510·20
29		1615·95
30		1721·70
31		1827·45
32	121·95	1933·20
33		2055·15
34		2177·10
35		2299·05
36		2421·00
37	138·15	2542·95
38		2681·10
39		2819·25
40		2957·40
41		3095·55
42		3233·70
43	154·35	3371·85
44		3526·20
45		3680·55
46		3834·90
47		3989·25
48	170·55	4143·60
49		4314·15
50		4484·70
51		4655·25
52		4825·80
53		4996·35
54		5166·90
55		5337·45
56	182·70	5508·00
57		5690·70
58		5873·40
59		6056·10
60		6238·80
61		6421·50
62		6604·20
63		6786·90
64	206·10	6969·60
65		7175·70
66		7381·80
67		7587·90
68		7794·00
69	229·50	8000·10
70		8229·60
71		8459·10
72		8688·60
73		8918·10
74	252·90	9147·60
75		9400·50
76		9653·40
77		9906·30
78		10159·20
79	276·30	10412·10
80		10688·40
81		10964·70
82		11241·00
83		11517·30
84		11793·60
85		12069·90
86		12346·20
87		12622·50
88	292·50	12898·80
89		13191·30
90		13483·80
91		13776·30
92		14068·80
93	308·70	14361·30
94		14670·00
95		14978·70
96		15287·40
97		15596·10
98		15904·80
99	324·90	16213·50
100		16538·40
101		16863·30
102		17188·20
103		17513·10
104	341·10	17838·00
105		18179·10
106		18520·20
107		18861·30
108		19202·40
109		19543·50

2·25 kips per lineal foot

Distances from first wheel	Sum of loads	Moments of all loads to left
109	341·1	19543·50
110	343·35	19885·725
111	345·6	20230·20
112	347·85	20576·925
113	350·1	20925·90
114	352·35	21277·125
115	354·6	21630·60
116	356·85	21986·325
117	359·1	22344·30
118	361·35	22704·525
119	363·6	23067·00
120	365·85	23431·725
121	368·1	23798·70
122	370·35	24167·925
123	372·6	24539·40
124	374·85	24913·125
125	377·1	25289·10
126	379·35	25667·325
127	381·6	26047·80
128	383·85	26430·525
129	386·1	26815·50
130	388·35	27202·725
131	390·6	27592·20
132	392·85	27983·925
133	395·1	28377·90
134	397·35	28774·125
135	399·6	29172·60
136	401·85	29573·325
137	404·1	29976·30
138	406·35	30381·525
139	408·6	30789·00
140	410·85	31198·725
141	413·1	31610·70
142	415·35	32024·925
143	417·6	32441·40
144	419·85	32860·125
145	422·1	33281·10
146	424·35	33704·325
147	426·6	34129·80
148	428·85	34557·525
149	431·1	34987·50
150	433·35	35419·725
151	435·6	35854·20
152	437·85	36290·925
153	440·1	36729·90
154	442·35	37171·125
155	444·6	37614·60
156	446·85	38060·325
157	449·1	38508·30
158	451·35	38958·525
159	453·6	39411·00
160	455·85	39865·725
161	458·1	40322·70
162	460·35	40781·925
163	462·6	41243·40
164	464·85	41707·125
165	467·1	42173·10
166	469·35	42641·325
167	471·6	43111·80
168	473·85	43584·525
169	476·1	44059·50
170	478·35	44536·725
171	480·6	45016·20
172	482·85	45497·925
173	485·1	45981·90
174	487·35	46468·125
175	489·6	46956·60
176	491·85	47447·325
177	494·1	47940·30
178	496·35	48435·525
179	498·6	48933·00
180	500·85	49432·725
181	503·1	49934·70
182	505·35	50438·925
183	507·6	50945·40
184	509·85	51454·125
185	512·1	51965·10
186	514·35	52478·325
187	516·6	52993·80
188	518·85	53511·525
189	521·1	54031·50
190	523·35	54553·725
191	525·6	55078·20
192	527·85	55604·925
193	530·1	56133·90
194	532·35	56665·125
195	534·6	57198·60
196	536·85	57734·325
197	539·1	58272·30
198	541·35	58812·525
199	543·6	59355·00
200	545·85	59899·725
201	548·1	60446·70
202	550·35	60995·925
203	552·6	61547·40
204	554·85	62101·125
205	557·1	62657·10
206	559·35	63215·325
207	561·6	63775·80
208	563·85	64338·525
209	566·1	64903·50

BARBER & YOUNG,
BRIDGE AND STRUCTURAL ENGINEERS
TORONTO.

FIG. 3

$$V = \frac{6604.2}{72} - 12.15 = 79.575 \text{ kips},$$

thus shortening the work sufficiently to effect a saving of time in a number of such computations, much greater than the time taken in listing the moments for the intermediate points between the wheels.

Again, let it be required to find the live-load moment, M, at the centre panel point of a truss (Fig. 2) of 200-ft. span made up of 8 panels of 25 feet each, with wheel 13 at the point. Employing the concise form of moment table in common use, the calculation would be:

$$M = \left(\frac{19543.5 + 341.1 \times 65 + \frac{1}{2} \times 2.25 \times (65)^2}{200} \right) \times 100 - 9147.6 = 14086.5 \text{ kip-feet.}$$

Employing the more extensive table this becomes:

$$M = \frac{46468.125}{200} \times 100 - 9147.6 = 14086.5 \text{ kip-feet.}$$

Where the right-hand support falls in between the points an even foot apart, results sufficiently accurate may be obtained by interpolation.

In testing for maximum shear and moment, where a portion of the uniform load is on the span, a saving of time is also effected by being able to read directly from the table the total load on the span for any assumed position of the loading.

RAILROAD LOCATION.*

W. G. SWAN, B.A. Sc.

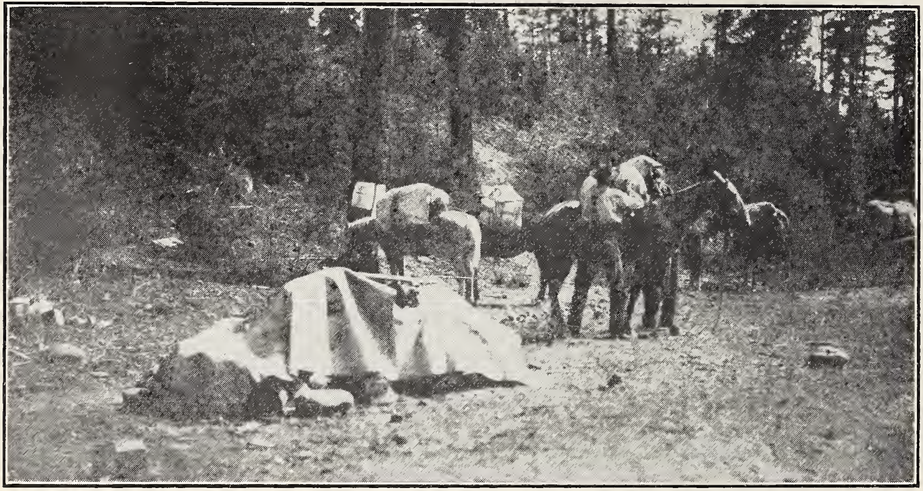
Of men who find their way into railroad engineering only a very small percentage take up the location branch of the work. This is natural enough, since the demand for locating engineers is comparatively small. Every construction engineer who follows this line of work will, however, find it greatly to his advantage to have a competent knowledge of railroad location gained only by experience in the field. Revision of the located line usually falls to the lot of the man on construction. If the engineer would do this to best advantage he must have a thorough knowledge of location work.

The locating engineer should understand fully the conflicting interests which are to govern his choice of a route. Very little ability in this branch of work is required to locate a line which could be constructed, and over which trains could be operated. What is desired generally, however, is the best line which will give, if possible, cheapness in construction as well as cheapness in operation. Where the choice in locaton is free from political or other allied interests, the three important factors governing this choice are the initial cost of construction, the operating expenses per train mile, and the proximity of the line to centres of trade. The initial cost should be a minimum, the operating expenses per train mile should be a minimum, and the location of the line should be such that the greatest amount of traffic will find its way over the company's lines. To maintain a low initial cost, especialy in rough country, will invariably mean heavy grades and sharp curvature. Heavy operating expenses will naturally accompany this class of construction. We have at once two conflicting interests which bear on the selection of a route. The happy mean might solve the difficulty, and probably does in some cases, but the greatest factor in the solution will always be the financial status of the construction company.

---

*Read before the Civil Section of Engineering Socieiy, Nov. 1909.

Cuts of this article courtesy "Canadian Engineer".



Pack Train leaving Junction of North Thompson and Clear Water Rivers, B.C.

On this account the engineer should be given to understand fully the allowable first cost of construction, that he may not select a line which will be beyond the means of his company, and which might later be rejected because of prohibitive cost. Ample time should always be allowed for the selection of the best possible route, since the cost of location forms but a very small portion of the total expenditure necessary to construct the railroad complete for operation.

Before taking the party into the field it is altogether advisable that the locating engineer go over the proposed route, making what is known as a reconnaissance survey. Not infrequently a whole party is placed in the field to make the reconnaissance survey. This is generally conceded to be a mistake. It leads invariably to backing up, re-running line, and adds materially to the total cost of obtaining a final location. Very often where a choice of routes is considered an able man will see in going over the ground the superiority of one route over a second. When no such apparent superiority exists, the engineer in making his reconnaissance will decide upon the necessity of running alternate survey lines with his party in the field. The reconnaissance survey made by the locating engineer before taking his party into the field will always present the results which arise in the blind running ahead of the initial survey through unknown country, where without warning a "dropping off" or "stepping up" place is encountered by which, or through which, the construction of a line would be a physical impossibility. Prior to setting out upon this reconnaissance survey it will be of invaluable aid to the engineer to procure the latest and most up-to-date maps of sections of the country through which the proposed line will run. "A fund of valuable information will often be obtained from this source." The most reliable topographical maps should be taken into the field on all occasions and consulted frequently. In England, where the Ordinance Department has prepared with utmost care topographical maps of all portions of the country, the location is projected in the office on these maps, their accuracy being such as to make it unnecessary, except in unusual cases, to place any survey party in the field. Furthermore, the engineer will find it profitable on his reconnaissance to have accompany him, if possible, some one who is acquainted with the particular section of country under consideration. Usually an aneroid barometer, a surveyor's box compass, and possibly a hand level will be sufficient in the way of mathematical instruments for the necessary observations. A record of all information likely to be of value later on should be kept during this survey.

The reconnaissance completed, the engineer is now in a position to organize his party for the field. The preparation necessary for taking a party into a settled section to locate is small in comparison with that required prior to taking a party into a rough, unsettled district. The make-up of the party in each case will be about the same, but the question of outfit and supplies necessary for carrying on work in an unsettled section of country is no small consideration. In settled country it will be found more economical to have the party board at small hotels and farm houses along the route, since camp equipment always necessitates a large outlay for the usual party of from twelve to eighteen men. The locating engineer, or chief-of-party, as he is usually termed, should either know personally the men he is about to take into the field or have them well recommended. An incompetent man is frequently retained on a party simply because the distance to market is too great to permit the getting of a new man. Trouble to the same extent will not, of course, be experienced in working through settled country. While there probably exists no healthier occupation in healthy climates than railroad location work, yet it is not a sick man's occupation.

It is healthy work only for a healthy man. One of our reliable texts on railroad work says: "The man on location work will probably work from 14 to 16 hours per day." This seems to be placing figures at their maximum value, but there is no question as to hours being long, the work heavy, and hardships not a few. I venture to say, however, that where conditions are not beyond human endurance, no day seems half so short as a busy day spent in the field on location work.

A few words here with regard to the personnel of the party to be taken into the field to make the preliminary and final surveys. It has been said of the chief-of-party that his only duty is to keep his eyes open. While this is probably of greatest importance, he must have a thorough knowledge of the duties of each man of his party (preferably gained by having occupied at various times the individual positions) in order that he may know whether or not accurate and conscientious work is being done. He must have the sympathy and good-will of his party to obtain best results, and this will be gotten only in return for his own. He must be capable if he would hold their respect; should have good control of his temper, a little righteous indignation not being out of place at the right time. He should not find it necessary to stand on his so-called dignity to keep his men in what he would consider rightful places. The competent man will get best results with greatest harmony in his party. He should not work his men on Sundays, nor call rainy days Sundays and work the next Lord's Day which comes along. There is usually plenty of work for a rainy day in camp.

The transit-man is the chief's right-hand man, and should always wherever possible act up to it. He should be rapid and accurate with his work, especially in rough country, where set-ups are frequent and difficult. He should not be called upon to run line and do transit work at the same time; his work is very exacting, and he cannot under such conditions do justice to either. He must not try to put it over his men if he would get best results. Don't feel big because you are the transitman, or, at least, don't let anyone know it if you do. They say you don't need to when you are chief.

The leveller, like the transitman, should work quickly and accurately. In his levelling he should check his turns in the field and establish his bench-marks only on his checked calculations. If the checking be left until reaching the office at night an error might be found which would necessitate changing the marked elevations on bench-marks perhaps for miles back.

The topographer should be a man competent to take reliable, accurate and intelligent notes, and should be able to work rapidly if he would keep pace with the rest of his party.

The rodman and chainman should be active, careful and intelligent men, who have an interest in their work. In open country the progress of the party will depend largely upon the rate of travel of the chainmen. The chainmen, or, perhaps, to be more specific, the head chainman, is the pace-maker. Never let a lazy man occupy head chainman's position, nor anyone who, perhaps, through no fault of his own, cannot walk rapidly.

The field draughtsman should be neat, rapid and accurate with his work; should be something of a specialist and mind-reader, to be able to decipher all field notes which are turned into the office.

Hell Gate, North Thompson River, B.C.

The Fore-picketman, who is usually one of the axemen, should be able to run a straight line through the bush without continual aid from the transit. His eyesight should be good to permit his taking signals from the transitman. The rear-picketman's post, in the writer's opinion, is bset left vacant. A good cross-head, firmly set, is always available, though some times picked up with difficulty from the transit; but a rear picketman, when he is wanted, who can find? Do not of necessity choose the axeman who can chop the biggest tree in the shortest length of time. Select the man who is willing to take his chance in both pleasant and unpleasant work. Class number one probably represents, or is represented by, the lumber-jack. The wise chief will have no place on his party for the lumber-jack. He is all right just so long as he can stand on the high and dry ground and chop the big trees, but when it comes to cutting out the underbush in the wet places he is found wanting. He is, furthermore, a born grumbler; pass him up. It has been said in the Good Book the last shall be first. This will undoubtedly apply to the cook. Unless he be of that variety who accepts cook's position on a party as a means of obtaining an outing. The chief should select a cook of whom he has a personal knowledge, or who comes recommended at first hand. The writer has in mind a case where the cook learned to make bread at some friend's place the night before he accepted cook's position on the party. At the end of a week the cook tried to sell out to one of the axemen, whom he learned understood something of cooking. At the end of the second week he was not given the option of selling out; he was put out. A party has been run for weeks with the chief laid up or absent, but never for more than one day with the cook and assistant off the job. He runs the chief a very close second for first place on the party.

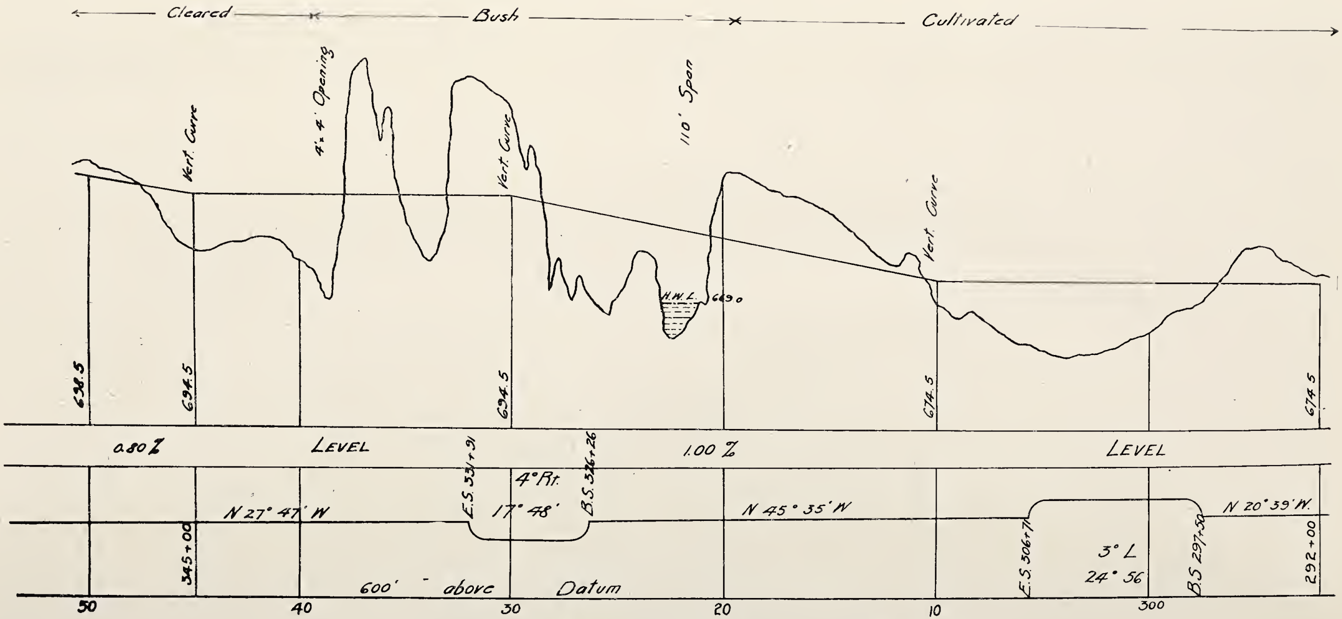
A few remarks will probably be in order here as to the outfitting of a party to be sent into the field in an unsettled district. It is customary for the members of the party to outfit themselves with boots and clothing. While surveys afford good opportunity for wearing out old clothes, these old clothes should be made of stout material if they would stand the wear and tear of rocks and bush. Good overalls, or, better still, whipcord clothing, give excellent service. Do not fail to supply yourself with strong, well-fitting boots, as nearly waterproof as possible. A good deal of walking falls to the lot of the members of the survey party in one day, and it is absolutely necessary that comfortable and substantial footgear be used. The supply of blankets will depend upon the section of country and the time of the year during which the survey is being carried on. Seldom does one find the members of a party lacking in ample supplies of the above-mentioned, but rather too often finds them, and especially the inexperienced ones, starting out, each with an outfit sufficient for himself and several others.

Amongst the general supplies there should be taken into the field a good, substantial, and not too large stationery box, preferably made of oak, and some useful form of collapsible drafting table, built of well-seasoned pine. That portion of the supplies, however, of most importance and requiring greatest care in selection is undoubtedly the food supply. Different cooks use different quantities of the same cooking materials, so that it is usually advisable to consult the cook in the purchases. Be it understood, however, that no party should venture into the field without an abundant supply of "long, clear," beans and prunes. No railroad line in this country has ever been brought to completion without the frequent application of these three national railroad builders. It may be said generally that one and one-half tons of good supplies are necessary for a party of eighteen men for one month's time. For details, Lavis on "Railroad Location" gives a very complete and reliable list. The Transcontinental Railway's book of instructions to engineers also contains a very complete list. In addition to the food supply there should also be a complete outfit of cooking utensils and general tools, together with a medicine chest.

In considering the actual preliminary survey, a few details of the methods of beginning the survey might be instructive. The true azimuth of the initial course is required as a basis for further calculation and reduction. This azimuth can best be obtained by an observation on the sun or polaris, or preferably both. It may also be obtained by tieing into some reliable land line of known azimuth, preferably a line established by the Dominion Lands Survey, since many of the Provincial Lands survey lines are very unreliable. A datum plane for the levels must also be established. Dominion Geographer James White's book of "Altitudes in Canada" will be found a most useful and convenient reference as a means of obtaining a starting point with the levels. Therein is contained a list of altitudes referred to mean sea level as datum, of all railway points, and of the principal rivers and lakes of Canada.

Preliminary Survey.

The reconnaissance survey will have confined the best location line to a given belt of country; in the preliminary survey the line is made to follow the particular ground within this belt which seems best adapted to the construction of a railway. This preliminary line is run in a series of chords or straight lines, changes in direction being introduced to fit the ground. These angular changes of direction are measured with the transit, the points of set-up being termed hubs or transit points. A continuous chainage begun with station 0+00 at the initial hub is carefully carried forward by the chainmen, station stakes being driven at each 100-foot point, and additional guard stakes marked with the chainage to the nearest tenth of one foot driven at hub points. The transitman will record the chainage of each hub with the amount and direction of the angle turned off. From this data can be derived the information whereby the plan of the line as actually laid down in the field can be plotted in the office. The profile of the ground is fixed by the levels. The leveller will take readings at each station point and at all intermediate points where breaks occur in the general lay of the ground. Lastly, by means of



Profile Shewing Section of Location Line cross-sections or contours, the topographer will make a careful determination of the natural run of the ground on either side of centre line to given distances, depending on the nature of the country. He will also locate with reference to the centre line all river banks, roads, drainage, ditches, and in settled districts the position of all buildings within these fixed limits. In rough country where abrupt changes in the ground occur, the cross-section method can be used to best advantage since contour lines would lie too close to one another in such country, giving a plan likely to be somewhat confusing because of a multiplicity of lines. Nor will the contour method be as serviceable in very even country because of a lack of contour lines. In undulating country, however, such as we find largely in the prairie, no other method of topography is quite equal to contouring.

Only the most accurate transit and chainage work can be tolerated on the preliminary survey since the final location is laid down relative to this preliminary lines. A great deal of time, however, is often spent in unnecessary detail and accuracy in laying down the preliminary line to fit precisely particular sections of the ground. The preliminary survey of the entire proposed route should first be completed, since one section of a final location might be run to give easy curvature and light gradients, while at some other section of the line it would, for the same cost per mile, be utterly impossible to maintain these high standard of grades and curves.

The rate at which the preliminary surveys should be pushed through will depend entirely upon the nature of the country. The rate at which it is put through is often another question. In heavy bush a mile to a mile and a quarter is good work with a party of five or six axemen, while in open country, five to six miles constitutes a very fair day's work. In very rough mountainous country 3,000 feet of line run might represent a very hard and heavy day's labor, while in open country under most favorable circumstances seven or eight miles is occasionally run in one day. Through a very short-sighted policy it sometimes happens that the railway company will not make expenditures unless immediate and direct results be shown therefor; the party may be poorly equipped with supplies, may be poorly provided with transportation facilities and lastly the men as very often happens.

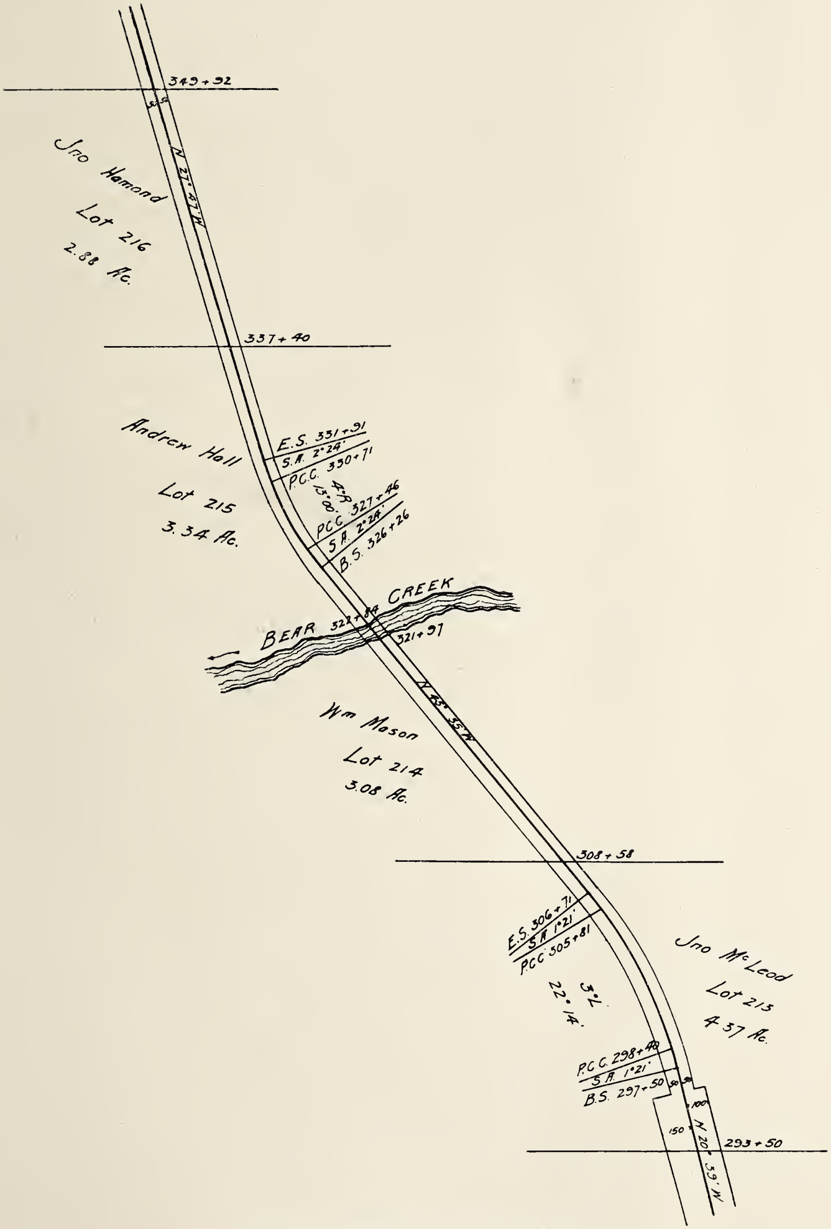
Before passing from the subject of preliminary surveys it would be well to consider briefly the methods employed in plotting the work in the office. The preliminary profile will be plotted on regular "profile paper." On it should be noted all water-courses with proposed openings, the nature of the country, wooded or otherwise, and the positions of all bench marks established. There is no alternative method of profile plotting. In preparing plans, however, we have a choice of methods. The scale of the plan will depend upon the nature of the country. In open easy country a scale of 400 feet equal 1 inch, will give a plan amply large for all purposes, while in rough localities a scale of 100 feet or 200 feet equal one inch, will be found more satisfactory. The system of latitudes and departures will be found most accurate and satisfactory in plotting the preliminary and other plans. It entails somewhat more work than does the "protractor" system, but errors are local not accumulative, as is the case with this latter method. Weather conditions will appreciably affect the plan paper, causing shrinkage or lengthening when the atmosphere is alternately dry or humid. The draughtsman should be careful not to allow errors to creep in from this source.

Final Location.

Let us now suppose the preliminary survey completed to the satisfaction of the engineer. There remains to be run now, only the final location line. Some very good location work has been done by laying down in the field, tangents to fit the ground, joining up the extremities with suitable curves. A much more reliable and more rapid method of obtaining a final location line has since come into general use, known as "projected location." With all the available information plotted on the preliminary plan, the engineer studies out this plan and profile, thus enabling him to lay down or project upon his plan the best possible line desired, always keeping well in mind the requirements of the completed road, low initial cost and cheapness in operation. In light open country it will be found to best advantage to locate or lay down on the plan the tangents best suited to fit the ground, connecting them up with easy curves. In rough country on the contrary it will be found more advantageous to fit the ground with the best suited curves, linking them up with tangents. This projected line which is now laid down in the field is called the location line. Frequently in rough country where errors in chainage creep in so easily it is found necessary to re-run sections of the location line to get the best suited ground. Such rerunning of line will be done most economically with the survey party in the field, and should not if avoidable, be left for correction to a small revision party which later may be put in the field. Revision should be reduced to a minimum in a well located line.

The location line will be laid out in a manner similar to that employed on the preliminary line with possibly one exception,—all tangents are joined up with regular railway curves. The levels will be taken as before, the leveller as well as transitman, booking any information which is likely to be of value later in obtaining a preliminary estimate of cost or such as may be of value in construction. The topographer should locate all land lines intersected by the location line, should obtain the lot numbers and names of owners, at the same time fixing the position of all buildings lying within the proposed right-of-way. He should further give particular attention to determining with reference to centre line the position of all water courses likely to have a bearing on the construction of the line.

Plan and profile should be made of the final location line em-



Section of Plan of Location Line

bracing all of the above information. The Dominion Railway Commission require that plan and profile of final location filed shall be to a horizontal or plan scale of 400′ = 1″ and a vertical scale of 20′ = 1″. On the plan there shall be shown the beginning and ending of each curve with its degree and total angle of curvature, the width of the right-of-way, all varying widths being indicated, the "plus" of every intersecting land line, lot numbers, owners' names, and area of the proposed right-of-way to be taken, the position of all buildings within the right-of-way, and all watercourses of consequence. A book of reference must be compiled giving all right-of-way information. This book of reference is usually attached to one end of the plan. The profile must show all grades and alignment notes, must indicate the nature of the country, and the proposed openings for all watercourses. High water levels for all important watercourses should be marked. All such plans and profiles should be certified to by the president or vice-president of the company, and by the company's engineer.

Grades.

A few remarks with regard to selecting the grade lines. It is usual in construction work to aim at as nearly as possible a balance between excavation and embankment quantities. But just as the lack of material from a cutting does not necessitate a low embankment and heavy grades, neither should good grades be sacrificed in an endeavor to prevent the wasting of material from cuttings. As regards changes of grade, it may be said definitely the summit of a grade should never occur in an embankment nor should the foot of a grade ever occur in a cutting.

Before leaving the question of final location, a few remarks on the standard railroad of to-day will not come amiss. The maximum degree of curvature for this class of road shall be three degrees per 100 feet of curve, all curves of sharpness exceeding 1° per 100′ of length being eased off to their tangents by means of the spiral of transition curve.* The maximum grade shall be 0.4′ per 100′ of length, and shall be compensated for curvature at the rate of 0.04′ per 100′ for degree of curve. The 0.4 per cent. grade represents practically a level line where this ruling grade comes within station ground limits, since the locomotive which can start its train on the level can maintain a speed of 15 miles per hour against this grade. Velocity grades exceeding the ruling grade are not objectionable where such are unavoidable. They are, however, worthy of considerable study by the engineer before making use of the same in his work.

A point of seemingly small consequence in running of railroad location lines but one which has considerable bearing on further developments is the treatment of the land-owners and their property, through settled districts. The company is, of course, liable to any damage to property accompanying the carrying forward of the survey, but a great many petty and unnecessary annoyances are often heaped upon the property owners through carelessness and disrespect. Landowners through whose property surveys may be carried should be treated with courtesy and respect, by the chief and party, while allowance should be made for the ignorance of the average property owner of such matters, and patience exercised therewith. The members of the location party are probably the first representatives of the railroad company with whom the landowner meets. His first impressions, the most lasting, will be formed from his acquaintance with the location party, and he will base his opinions accordingly. Careful treatment of property and courtesy towards the owners will make the work of the right-of-way agent much easier and more pleasant, and is a matter of economy worthy of consideration by the company. A story is told of a location party which was running line through a certain farmer's property. The farmer who was naturally inquisitive as to why these men should be on his property, went out to make enquiries of them. The chief answered him curtly that he held in his pocket a paper which gave him the right to enter in upon any property, public or private, at such time as suited him. The farmer made no reply, turned on his heel and sauntered back to the barnyard. Here he untied his bull and turned him loose into the field. The bull made straight for the party, who perceived him only in time to shin up some nearby trees. The men after waiting vainly for some time in hopes the bull would retire, shouted to the farmer to come and take the animal away. The farmer who could evidently appreciate the joke, shouted back the suggestion that the chief show his paper to the bull.

---

*A minimum distance of 300 feet should be left between curves of opposite direction, while 500 feet is the minimum allowable distance between two curves of the same direction.

Estimating.

In closing, we give the details of a preliminary estimate of 100 miles of line actually located and constructed. Preliminary estimates are invariably exceeded. A solution to the difficulty might be found by applying in moderation the method of estimating machine shop work. Carefully estimate the cost of the work and multiply by two. In the present instance the final cost exceeded the preliminary estimate by an amount slightly less than 10 per cent.

PRELIMINARY ESTIMATE OF COST.

(a) Grading (including overhaul, piping and culverts)—	
50 miles at $1,650 per mile	$ 82,500.00
30 miles at $3,500 per mile	105,000.00
20 miles at $6,000 per mile	120,000.00
(b) Right-of-way—	
520 acres at $200	104,000.00
(c) Rails, fastenings and ties—	
11,500 gross tons rails and fastenings at $35	402,500.00

271,000 ties at 40c.	108,000.00
100 miles of tracklaying at $300 per mile	30,000.00
(d) Ballasting—	
300,000 cubic yards at 35c.	105,000.00
(e) Crossing plank, sign boards, cattle guards—	
70,000 F.B.M. hemlock at $30	2,100.00
8,000 F.B.M. pine at $40	320.00
(f) Fencing—	
68,000 rods at 85c.	57,800.00
640 gates at $5	3,200.00
(g) Bridge steel and masonry—	
300,000 lbs. steel at 5c.	15,000.00
1,000 cubic yards concrete at $10	10,000.00
(h) Timber trestlework—	
300,000 F.B.M. at $45	13,500.00
Drift bolts, dowels, washers, etc.	275.00
(i) Engineering (including location)	22,500.00
Total estimate of cost	$1,181,695.00
Estimated cost per mile	$11,816.95

It will be noted that the cost per mile of construction, about $12,000, must necessarily represent light work. Such was the case, the greater portion of the country through which the line passed being prairie-like in nature. The maximum allowable grade was a 1 per cent. compensated for curvature, while the sharpest curve employed outside station ground limits was 5° per 100 feet of length.

BOOSTERS AND THEIR USE IN STREET RAILWAY OPERATION.*

L. S. O'DELL

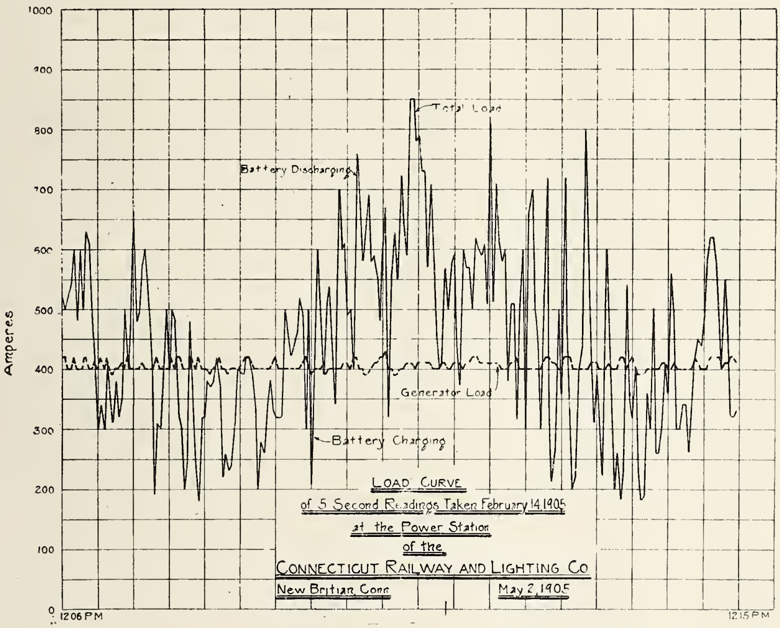
Boosters are a special type of generator and they are usually operated in a circuit for the purpose of adding to or subtracting from an e. m. f. already existing there. Generally the class of service on which they are employed calls for a machine which will carry heavy currents and at the same time generate a relatively small e. m. f. acting positively or negatively as required. In street railway service boosters are employed in connection with storage battery regulation and, to a less extent, as a means of preventing excessive drop at the outlying terminals of feeder lines.

A storage battery system may be used as an auxiliary in a power plant in either of two ways. If the plant handles both a power and lighting load, fairly steady peak loads may occur at particular times of the day. At such times a battery may be used to help the generators carry the load, the battery being recharged at some time when the load is light. Such a battery is also much used for lighting purposes at times when it is desirable to shut down the generators entirely. When, however, the load fluctuates within wide limits as is nearly always the case in street railway service, a storage battery system is used to equalize the load upon the generators, the battery helping out the latter when the load is high and being recharged when the load is light. The total load curve, Fig. 1, illustrates such a load. To attain these conditions a special regulation system must be installed in connection with the storage battery.

---

*Read before Electrical Club, Nov., 1909.

The e. m. f. of one fully charged cell on no load is about 2.05 and when discharging full current this falls to about 1.95 owing to internal drop. When the cell is being charged the internal resistance increases very much because of polarization and a final impressed voltage of 2.65 is necessary to fully charge the cell. Hence when a battery, composed of a large number of cells in series, is employed on intermittent service as in the former case mentioned, and connected in parallel with generators over constant voltage mains some method must be used to prevent the drop of battery voltage below that of the line. This may be done by switching in more cells as the voltage falls or by using a booster in series with the battery, the booster automatically adding the necessary voltage to that of the battery. Unless there is some means of increasing the line voltage, the battery



can only be fully charged by decreasing the number of cells in series so as to have 2.65 volts available for each cell or by using a booster in such a way that its voltage will be added to that of the line so as to give a voltage 2.65 times the number of cells. The latter is by far the more common method. In the second case mentioned above the load fluctuates often and the battery must be in continual operation. Such operation is only successful when a booster and automatic regulation system is used. Whatever be the load variations on the line, the generator load should be practically constant as indicated by the curve of generator loads, Fig. 1. Hence on overload the regulation should be such that the booster will not only make up the difference between battery and line voltage, but add a voltage to that of the battery which will be sufficient to enable the later to discharge such a current as will carry all the overload, that is the load in excess of the predetermined generator load. On underload the booster e. m. f should reverse and be of such a value that this e. m. f. along with that of the line will force enough current through the battery to hold up the load on the generators, which supply this current, to its proper value.

Boosters are usually driven by ordinary shunt motors but any source of power, such as engines or turbines, may be employed. Such is understood to be the case in all the diagrams of Fig. 2, where only the battery, the booster, and the regulation systems are shown connected across the mains. Diagrams *a, b* and *c* show cases of a shunt generator used for boosting service. Under such circumstances the booster is generally only used to help charge the battery and an end cell switch as shown in *c* is used to gradually cut in cells and compensate for voltage drop. Such a machine will not automatically reverse and hence can only be used on intermittent service. If the booster is used to assist discharge the field must be reversed. Diagram *d* shows a series generator used as a booster. With average line load, there should be no discharge from the battery and its e. m. f. should equal that of the line. Suppose the load increases and the line voltage falls. Current flows from the battery through the booster to the line and this current exerting the booster creates an additional e. m. f. in the booster armature, which aids the battery to discharge. If the line load falls and the line e. m. f. rises, current will begin to flow from the line through the battery, and the subsequent booster excitation added to the line e. m. f. helps to charge the battery. Hence this system will work on either intermittent or continuous service but it is unsatisfactory and seldom used. Owing to residual magnetism in the fields the booster e. m. f. is sluggish in reversing. Furthermore, unless the iron in the booster magnets is worked at very low intensities, field saturation and armature reaction, which is a serious feature in all boosters owing to the relatively large armature currents carried, will prevent the e. m. f. generated from being anywhere nearly proportional to the current variations. Diagram *e* shows a compound generator used as a booster. Its regulation is a little better than with the series but it is not automatic.

Diagrams *f* and *g* illustrate types of what are known as differential boosters. They are practically the same in each case, the shunt and series windings acting in opposition to one another. With average line load and line voltage, the magnetizing effects of the two evils balance and if the battery e. m. f. equals that of the line, as it should, no current will flow in the battery circuit. An increase of load causes the series coil to predominate and an e. m. f. is induced in the booster such as well assist the battery to discharge. On under load the shunt field predominates, the booster assists the line voltage to charge the battery and the generator load is increased by the amount required for this charging. Such a system works very nicely

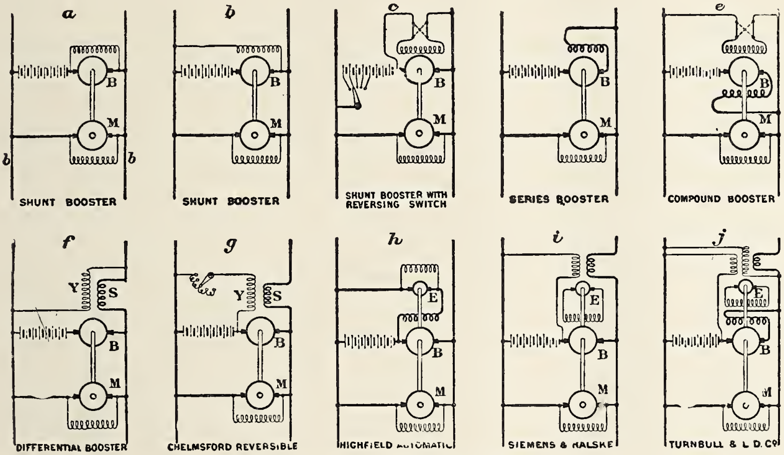


Fig. II. Types of Boosters.

when the battery voltage equals the line voltage on average load. If these are not equal the battery will take too much or too little of the load according as its voltage is higher or lower than that of the line. To overcome this tendency a third coil is inserted in series with the booster armature so that it acts as follows: If the battery voltage is high, current will flow from the battery through the booster armature and this auxiliary field to the line. The polarity of this field is such that the consequent induced e. m. f. opposes the flow of current and prevents its attaining any disturbing value. When the line voltage is higher than that of the battery, this auxiliary coil holds down the current which in this case tends to flow from the line through the battery. The magnetizing effects of this auxiliary coil should be small in comparison with the others, for if not this auxiliary coil will neutralize the action of the others and interfere with regulation. This it always does do to some extent.

In the differential types the booster is controlled by the simultaneous action of its three field coils. This construction involves a machine with very large fields and a considerable copper loss even though a shunt be used across the series field. Hence we have what are known as externally controlled systems, designed to avoid as far as possible the above difficulties. The last three diagrams illustrate the principle of the exciter-controlled booster set. The exciter is a much smaller separate generator usually driven by its own shunt motor. This machine excites a single shunt coil on the booster. In the Highfield automatic, the shunt field resistance of the exciter is so adjusted that the exciter e. m. f. balances that of the line and battery with average load under normal conditions. Then no current flows in booster battery or exciter circuit. Suppose the line load increases. The line voltage falls and both battery and exciter discharge onto the line. The current which now flows in the booster field generates an e. m. f. which assists discharge so that the battery will then carry the overload. On underload the exact opposite occcurs and the battery is charged. Should the battery get over or under charged, so long as the exciter e. m. f. is equal to that of the line, the battery will take care of the fluctuations of load. If the battery were overcharged on average load conditions it would tend to discharge both through the exciter and onto the line. This discharge current through the booster field generates an e. m. f. in the booster which opposes the tendency to discharge through it into the line and practically prevents that trouble so long as the line voltage holds up to normal. On undercharge the same line of argument will show that the apparatus automatically prevents the generators from charging the battery unless the line voltage rises above that of the exciter. Thus the same purpose is effected as that for which the third coil is employed on the differential types. In the last two diagrams of booster sets, the exciters are controlled by differential shunt and series windings just as in the first mentioned differentially controlled booster. The regulation is practically the same in both classes but the exciter controlled is the cheaper to operate owing to the decreased copper loss, the necessary field coils being much smaller. In the final diagram the extra shunt winding on the exciter and series winding on the booster, aid in giving better regulation, the series booster field being employed for the same purpose as in the differential types.

The Gould Regulation System, Fig. 3, is one much employed on this continent. This is an exciter controlled type but a counter e. m. f. generator as shown in diagram is also operated usually being driven by the same motor as the exciter. The field of this generator is excited by current from the main generators so that on average load the e. m. f. of the former balances that across the mains. Then no current flows in the exciter field and the rest of the system is inoperative provided the battery voltage equals that of the line. However, an increase or decrease in the generator load will cause current to flow in one direction or the other through the exciter field and hence current from the exciter energizes the booster so as to promote charge or discharge as required. The efficiency of regulation is unaffected by conditions of battery undercharge or overcharge, this very necessary condition following from the principle on which the system works. The object of the regulating apparatus is to keep the generator load constant at a fair average value. Any variation from this condition of affairs is at once corrected by the system so that in whatever state the battery charge may be, it cannot disturb the operation of the plant to any serious extent.

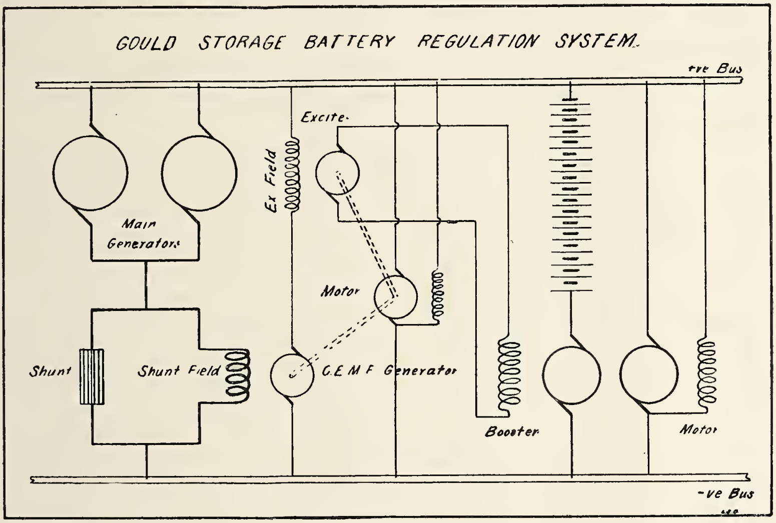


Fig. III. The Gould Battery Regulation System.

While the last system described gives a very efficient regulation, the exciter and counter e. m. f. generator with their driving motor introduce a considerable item of first cost and their operation involves a continuous though not very large expenditure of power. The Entz carbon pile regulator employs an externally controlled booster but the use of auxiliary generators is done away with. Fig. 4 illustrates this principle of operation. P and P^1 are carbon piles made up of a large number of circular sheets of carbon piled vertically. They are connected to the battery as shown. The solenoid about which line current passes acts against a spring at the other end of the lever and with average line current from the main generators the apparatus is so adjusted that the pressure on the two carbon piles is equal. Then the resistance of each will be the same and the drop across each pile will be half the battery e. m. f. The two parts of the battery and the two carbon piles constitute what is really a Wheatstone Bridge arrangement, and under the conditions above mentioned no current will flow in the branch containing the booster field. Any change in the generator load will, however, through the pull of the solenoid acting against the spring, cause the pressure on one of the piles to increase and on the other to decrease. This disturbs equilibrium and a current flows through the booster field in one direction or the other depending on whether overload or underload conditions exist. The consequent booster excitation aids to discharge or charge the battery as required. It should be noted that current is always flowing in the carbon piles. In a large station where a large booster is required a considerable current will be needed to energize the field of that machine, so it will be seen that the still greater current flowing continuously through the carbon piles involves a serious energy loss. Hence in some cases it has been found advantageous to use a separate exciter for the booster field and operate the exciter field by means of a carbon pile regulator.

All the systems described are more or less adjustable in their action, but this latter system is capable of a greater variety of adjustment than any other. All good systems can be set to carry any predetermined running load on the generators. This is done in the differentially controlled types by varying resistance in the shunt field circuit, in the Gould system by varying the shunt resistance across the counter e. m. f. generator field and in the Entz system by varying the tension of the spring which acts in opposition to the solenoid. Also, by the use of adjustable resistance in the field controlling circuits the sensitiveness of regulation may be varied at will, that is, the regulator may be set so as to maintain a steady load on the generators or may divide with them the load fluctuations in any desired proportion. Furthermore, the motion of the lever in either direction is limited by mechanical stops, so that when the overload or underload becomes so great as to send a current, to or from the battery, which may throw the circuit breaker on that line, further motion is prevented and any further load variations are carried by the generators. This is an important feature because the opening of the battery circuit breaker on overload is liable to throw a destructive load onto the machines or to throw their breakers, in which case total interruption of line service results.

The use of these regulation systems has only come into prominence during the last few years owing to the improvements in regulation obtained by some of the later systems. Most installations have been in connection with direct current street railway power plants where the loads are always extremely variable. Also in some other plants, such as those supplying power for electric drive in rolling mills, the load fluctuations are extreme and in the absence of some such regulation system the shocks due to sudden load changes would seriously decrease the life of the generators. A few storage battery plants are being operated in alternating generating stations but the rotary converters which must be interposed between the generators and battery form a considerable item of capital account. The more usual method especially in the case of large distribution systems is to install the batteries in substations. Then alternating current is generated and transmitted but at the substations is transformed to direct current, and used as such, the loads at the substations being equalized by a storage battery regulation system. This is also an expensive way of equalizing the load because of the number of battery systems and the consequent cost of maintenance. In both cases the load on the generators can be held practically constant. Such regulation would be very useful in the case of hydroelectric generating stations since it would practically dispense with the necessity of water-wheel governors. At all events the demands made upon such governors would be greatly reduced and the danger attendant upon their failure minimized.

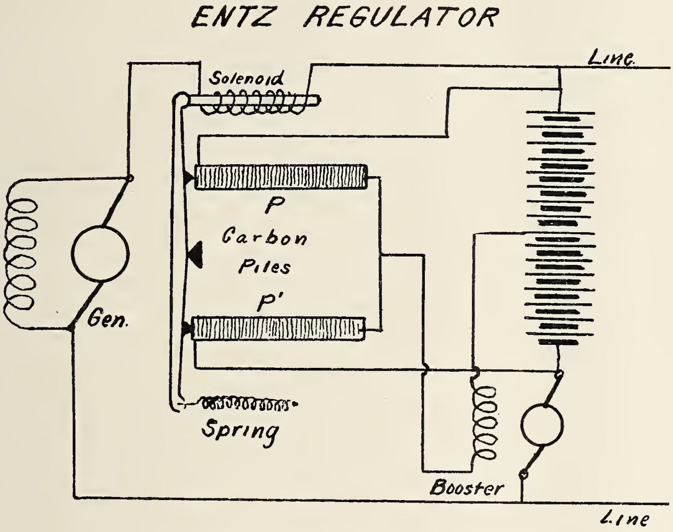


Fig. IV. The Entz Carbon Pile Regulator.

Besides doing away with load fluctuations and their incident wear and tear upon the generating machinery, the use of such systems carries with it other advantages. In the construction of new stations, the plant need only be of such a size that the generators will carry the average power to be delivered, and at times of peak load the station with the aid of the battery will carry far more than its generator capacity. This decrease in size of steam and electrical plant brings with it a decreased cost of maintenance. The machinery may also be operated at a load at which its efficiency is a maximum and both these latter points effect a continuous saving on the fuel bill.

Where such systems are installed in plants already operating the advantages derived follow much the same lines. They are often put in where increased demands for power have caused peak loads in excess of the generator capacity. Such a plant will obviate danger of burned-out armatures and prevent the opening of the circuit breaker when sudden load fluctfuations occur. It is often found that with a previously overloaded plant, part of the plant may afterwards be held in reserve or one unit after another may be shut down and the whole plant rebuilt or thoroughly renovated. The batteries also enable small railway lines which discontinue service during a part of the night to carry a lighting load all night with all the machinery shut down.

As previously hinted, boosters have another and entirely different use in connection with street railway operation. The drop on long feed lines especially at times of the day when the traffic is heaviest may go beyond its permissible limits and if over-compounding be resorted to, the voltage in the outlying parts of the system may be kept up, but the station voltage will become abnormally high. If a booster be placed in the feeder circuit and so adjusted that it will give boost equal to line drop the voltage at the remote terminal of the feeder line can be held up to that of the station. Negative boosters may also be used to compensate for drop upon he return circuit. With such a system the voltage generated at the station is really that of the generators, whose voltage is impressed on the line at the station and in addition the sum of the line drops on feeders and return circuits. This can only be done at the expense of extra driving power and the all important question is whether it would be better to use a booster or to install a heavier feeder line which is the only alternative by which excessive line drop may be prevented. On the one hand we have the continuous bill for the extra power and on the other hand a greater capital expenditure for the heavier copper line. It is found that in practically all circumstances a booster is an economical proposition only when it is used to prevent an excessive drop due to peak loads occurring for a few hours a day. A line drop which will make the booster a necessary auxiliary under average load conditions is never justified.

WATER COLUMNS FOR DEEP LEVEL MINES.

E. J. LASCHINGER, M.E., B.A.Sc.,* (Toronto)

The question as to the proper size for water columns for mines is one that always awaits decision when the details of mine equipment have to be decided.

The total cost of delivering the mine water to the surface may be considered as being made up of two parts:

1st. Actual cost of pumping or power cost.

2nd. The interest and redemption value of the pipe, plus maintenance of the pipe line.

The smaller the pipe the more power lost in frictional resistance to flow and the cheaper the pipe; the larger the pipe the less the power lost in friction and the greater the cost of the pipe. There must therefore be some size of pipe which will make the total cost a minimum for any given case.

A little reflection will show that the actual cost of raising the water against the static head does not enter into this question of pipe diameter, since that cost is a constant upon which size of pipe has no influence; so, also, regarding the cost and maintenance of the pump itself, because in any case the permissible amount of friction head is so small compared with the static lift that pumps need not be constructed stronger or made more expensive than is necessary, assuming only the static head with the usual safety margin. It is evident that the time of pumping has a bearing upon the size of pipe, for if pumping at a uniform rate goes on continuously, more total power is lost per day than if pumping at the same rate for only one shift per day.

The author's endeavor in this short paper has been to formulate expressions giving the average cost of water columns for depths up to, say, 2,000 ft. vertical, in terms of the diameter, and also the cost of horse-power lost in friction in terms of diameter, quantity of water, and time of pumping. Having obtained mathematical expressions for the total cost or value of the transmission line and the transmission losses in terms of the diameter of pipe and other factors, this equation is solved by the usual rules for finding minimum values, and that diameter deduced which will make the total transmission cost a minimum. This, then, gives us what may be called the most economical size of pipe.

PIPE COST AND VALUE.

A good heavy pipe for a pump column for high lifts will cost erected complete on the Rand:

$$s = d^{1.25} \qquad (1)$$

where s = cost in shillings per foot.

d = diameter in inches.

Table I herewith shows costs according to this formula for various sizes.

---

*President South African Association of Civil Engineers.

WATER COLUMNS FOR DEEP MINES

Size Inches.	Shillings per foot.	Size Inches.	Shillings per foot.
2	2.38	8	13 45
2½	3.14	9	15.59
3	3.94	10	17.78
3½	4.79	11	20.04
4	5.66	12	22.39
4½	6.55	14	27 09
5	7 48	16	32.00
6	9.39	18	37.08
7	11.39	20	42.30

Cost includes prime cost of pipe, flanges, joints, valves and fittings, bolts, erection, supports, engineering fees, administration charges.

VALUE OF PIPES

Interest=6% per annum.
Redemption=3½% Sinking Fund=
15.26% on 6 year's life.
6 84% " 12 " "
3 53% " 20 " "
Maintenance
5% " 6 " "
3% " 12 " "
1% " 20 " "

TOTAL VALUE FOR PIPE

On 6 year's life	26.26%	Per Annum of Capital
" 12 " "	15.84%	
" 20 " "	10.53%	

The total cost of the pipe line will therefore be:

$$S = \frac{Ld^{1.25}}{20} \qquad (2)$$

where S = total cost of pipe in £
L = length in feet
d = dia. in inches.

The real continual cost of the pipe line will depend upon the interest and redemption value of the capital cost, plus the cost of maintenance

$$J = \left(\frac{i + r + m}{12}\right) S. \qquad (3)$$

J = continual cost of pipe line in £ per month.
i = interest—annual.
r = redemption—annual.
m = maintenance—annual.

Take interest at 6 per cent. per annum.

Take redemption as a sinking fund bearing 3½ per cent. interest per annum, and taking three cases of pipe life of 6 years, 12 years, and 20 years respectively.

Take maintenance as—

5% per annum for a 6 years' life of pipe
3% per annum for a 12 years' life of pipe
1% per annum for a 20 years' life of pipe

For the three cases assumed we would have, therefore, the following values of J in equation (3):—

For pipe life of 6 years—

$$J_a = 0.0011\ Ld^{1.25} \qquad (3a)$$

For pipe life of 12 years—

$$J_b = 0.00066\ Ld^{1.25} \qquad (3b)$$

For pipe life of 20 years—

$$J_c = 0.00044\ Ld^{1.25} \qquad (3c)$$

Friction Loss and Power Cost.

The power lost in friction is found by multiplying the weight of water pumped per second into the time of pumping and the friction head. The friction head is given by the well-known formula:

$$H = z \frac{L}{D} \frac{v^2}{2g} \qquad (4)$$

where H = friction head in feet
z = co-eff. of friction
L = length of pipe feet
D = dia. of pipe feet
v = velocity of flow in feet per sec.
g = acceleration of gravity = 32.1.

From Prof. Unwin's investigation* of the best experiments on flow in pipes somewhat rough or incrusted, the author deduces:

$$z = \frac{0.044}{D^{0.16}} \qquad (5)$$

Assuming that a cubic foot of water weighs 62.5 lbs., expressing velocity in terms of quantity and diameter, and combining equations (4) and (5), we find that the horse-power lost in friction is:

$$P = 46.75 \frac{Q^3 L}{d^{5.16}} \qquad (6)$$

where P = horse-power lost in friction
Q = quantity in cub. ft. per sec.
L = length of pipe in feet
d = dia. of pipe in inches.

Assuming that electric pumps are used giving a combined motor and pump efficiency of 74.6 per cent., so that the cost of an electrical unit input represents the cost of a horse-power hour in energy delivered to the water, we would have:

$$c = \frac{kh}{240} \qquad (7)$$

where c = cost of water horse-power in £ per mo.
k = cost of electrical unit in pence
h = number of hours pumping per month

For the case of electric power at 0.6d. per unit:

$$c_1 = 0.0025h \qquad (7a)$$

For the case of electric power at 1d. per unit:

$$c_2 = 0.0042h \qquad (7b)$$

Combining equations (6) and (7), we have for the total cost of frictional losses where power cost 0.6d. per unit:

$$C_1 = 0.1169 \frac{h\,L\,Q^3}{d^{5.16}} \qquad (8a)$$

---

*A Treatise on Hydraulics—Unwin, A. & C. Black, London, 1907, p. 217.

and when power costs 1d. per unit:

$$C_2 = 0.1963 \frac{h\ L\ Q^3}{d^{5.16}} \qquad (8b)$$

where C_1 and C_2 represent total loss in £ per month.

The total continual cost of transmission may therefore now be written:

$$X = J + C \qquad (9)$$

Inserting letters K and M to represent the numerical values in equations of series (3) and (8):

$$X = K\ L\ d^{1.25} + \frac{M\ h\ L\ Q^3}{d^{5.16}} \qquad (10)$$

Setting the first differential ratio (assuming d as the variable) equal to zero, we get a condition of minimum:

$$\frac{dX}{dd} = 1.25KLd^{0.25} - \frac{5.16MhLQ^3}{d^{6.16}} = 0 \qquad (11)$$

Therefore:

$$d = \left(\frac{5.16}{1.25}\ \frac{M}{K}\right)^{0.156} h^{0.156} Q^{0.468} \qquad (12)$$

Where d represents the diameter in inches of the most economical size of pipe:

h = number of hours of pumping per month
Q = rate of pumping in cub. ft. per sec.

The sizes of pipe for the various conditions have been calculated and plotted in diagrams 1 and 3 for different cases. These diagrams will give by inspection the proper size with sufficient accuracy for general use.

Diagram 3 has been prepared to show graphically the costs involved in transmission losses for one set of cases. It will be seen that the curve showing the total cost of transmission has only one point of interest, and that is the point of minimum loss. It is also instructive to note that the losses do not increase rapidly on either side of the true economical diameter, but that it is best to err on the side of making the pipe slightly larger rather than smaller than the true economic size.

A few comments on points of interest may be noted:—

(1) Although these calculations have been made on the cost of pipe as given in Table I., a variation in price of pipe does not seriously affect the result, seeing that the diameter varies approximately as the 6th root of the cost. If piping as erected actually costs 50 per cent. more, the economical diameter is only 6 per cent. less, or if the actual cost of installation is one-half of that assumed, the diameter should be only 11 per cent. greater. The cost of lead-lined pipes for a head of 1,500 feet would be about double the costs assumed; this would make the economical diameter 10 per cent. less than the sizes shown in the diagrams.

(2) Higher velocities are permissible in large pipes than in small pipes.

(3) Length of pipe does not affect the economic size.

(4) With cheaper power it is advantageous to allow a greater frictional loss and save on the capital cost of installation.

(5) In temporary piping installations or with pipes having a short life it is economical to put in smaller pipes than when pipes have a long life.

(6) For continuous pumping pipes should be larger (other conditions being equal) than when pumping is intermittent.

(7) The sizes of pipe for different rates of pumping as given by the diagrams allow ample margin, since the co-efficient of friction has been taken for incrusted pipes and not for new pipes. Actual experience has, however, shown that frictional loss soon approximates to the condition assumed.

(8) With the sizes of pipe as given by the diagrams the frictional loss is small, or in other words the efficiency of pipe transmission is high, as the following table (II.) will show:

TABLE II.

Percentage ratio between frictional loss and static head for vertical lift.

Power Cost....	0 6d. per K. W. hr.				1d. per K. W hr.			
Pipe Life.....	6 Years		20 Years		6 Years		20 Years	
Pumping Time...	1 shift	3 shifts	1 shift	3 shifts	1 shift	3 shifts	1 shift	3 shifts
At 1 c. f. sec...	3.73	1 54	1.78	0.74	2.46	1.17	1.01	0.48
" 4 c. f. sec...	2 10	1.00	0.87	0.41	1.38	0.66	0 57	0.27

(9) Since the length of pipe does not affect the proper diameter, it follows that for a certain static lift it is economical to allow more total frictional loss in incline shafts than in vertical shafts in the direct proportion that the length along the incline bears to the vertical depth; in other words, in the inverse ratio of the sine of the angle of dip.

(10) It will be seen from an inspection of the diagrams that the most economical velocities of flow are quite moderate. With power at 0.6d. per k.w. hr. and continuous pumping the velocity range lies between 2½ to 4 ft. per sec., and with power at 1d. per k.w. hr, between 2 and 3½ ft. per sec. for ordinary sizes of pipe.

In conclusion, the author would say that there are very many points worth investigating in connection with this important subject of deep-level pump columns and pumping generally. Numerous instructive experiences might be related by those who have had to do with the design, installation and working of deep-level pumping plants, which would form the basis of an interesting and valuable discussion before this Association. This note has been confined to the study of only one of the many points involved in the design of plant, in the hope that the conclusions may be of some service to engineers and the mining industry.

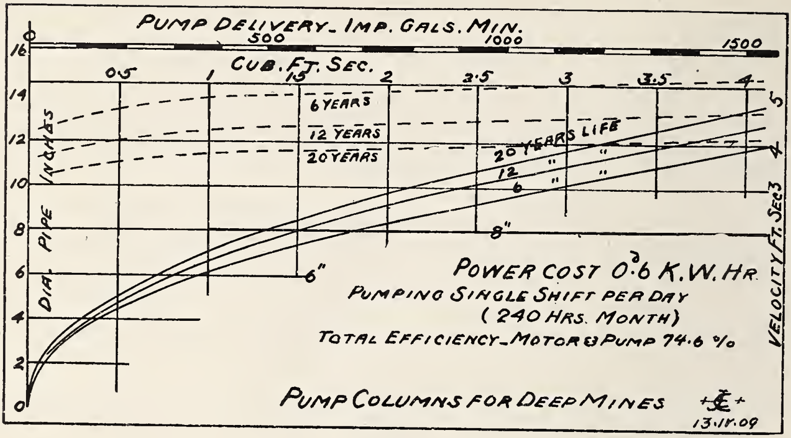


Fig. 1

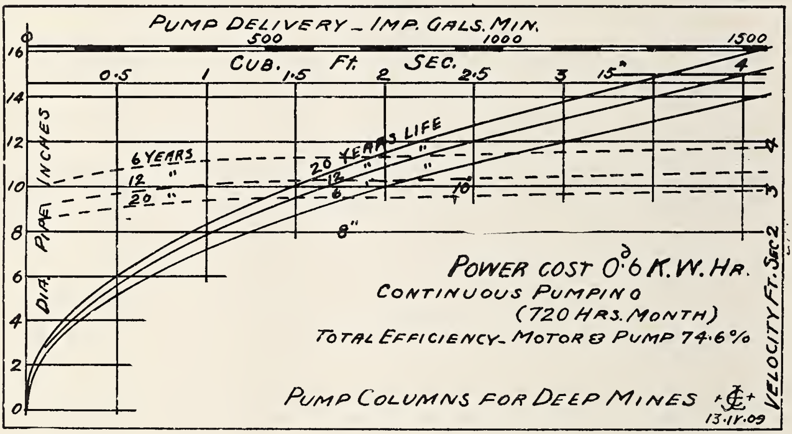


Fig. 2

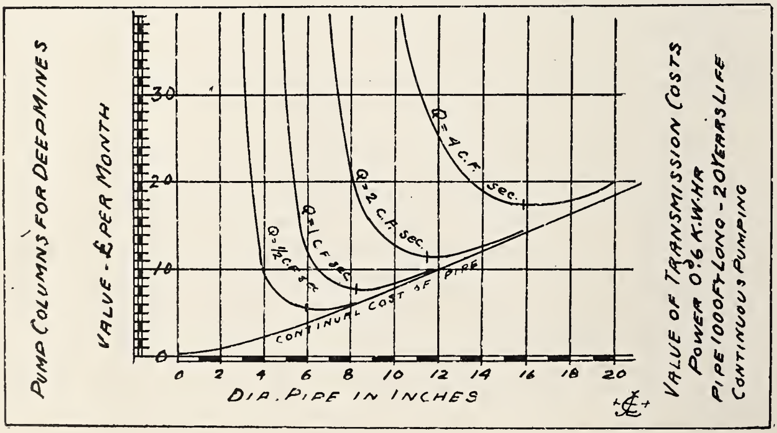
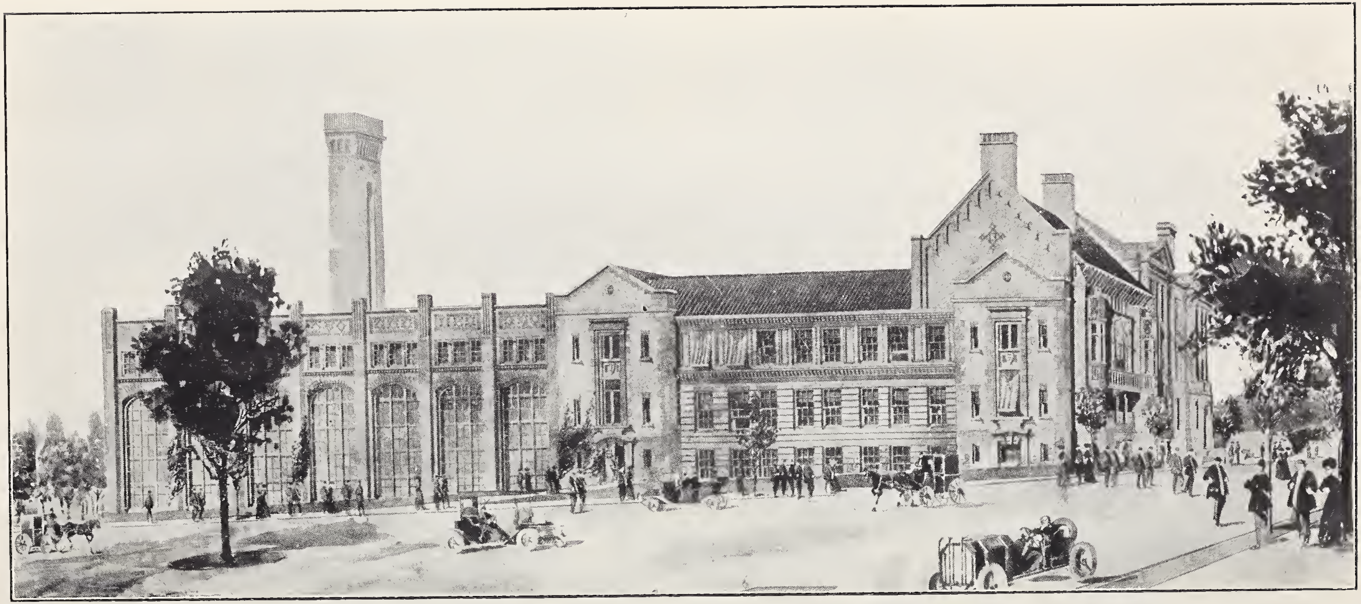


Fig. 3



Steam, Gas and Hydraulic Laboratory Building of the University of Toronto Darling & Pearson, Architects

This shows the building as it will appear when completed. At present the whole laboratory part is completed which comprises all of the building to the left of, and including, the first window to the right of those protected by awnings.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 FEBRUARY, 1910 New Series Vol. 3, No. 4

THE NEW LABORATORIES OF THE UNIVERSITY OF TORONTO, FOR STEAM, GAS AND HYDRAULIC WORK.

By Robert W. Angus, B.A.Sc.,
Professor of Mechanical Engineering.

The first engineering laboratory in Toronto was formally opened on February 24th, 1892, in the School of Practical Science which is now the Engineering Building of the Faculty of Applied Science and Engineering of the University of Toronto. This laboratory consisted of three departments: First, the department for testing materials of construction. Second, the department for investigating the principles governing the application of power, which department included the steam laboratory, the hydraulic laboratory and the electrical laboratory. The third department was an astronomical and geodetic laboratory.

In the steam power department there were two boilers, the larger of 50 H.P. capacity, a 50 H.P. Brown engine with condensers and pumps, and a machine for measuring journal friction and for testing lubricants.

The hydraulic division contained a three-throw pump driven from the Brown engine, a large impulse wheel, and two large tanks for orifice and weir experiments.

This equipment served very well at the beginning; there were not many students and thus a large number of pieces of apparatus was not necessary, and the apparatus actually installed was so well selected and suited the purpose so well that much valuable instruction was given on the machines mentioned.

As the work expanded and the number of students increased small additions were made, but up to the time the writer was appointed demonstrator in this work in 1898 the only additions were two reaction turbines, neither of which was set up for operation, and a crude type of centrifugal pump, together with tanks for calibrating the orifices and weirs already mentioned.

During the past decade great advances have been made in the development of power, more especially in Canada, where we have been appreciating to some extent the value of our water-powers. The gas engine has also been brought to a high state of perfection and suction gas has presented such great possibilities as to make it an important source of power.

Further, the work of the Engineering Faculty has been recognized by the people of the province in such a way that the attendance has increased by leaps and bounds.

For these and other reasons it has been necessary to increase steadily the equipment of the power department to illustrate the modern methods and also to provide sufficient apparatus for the increased number of students.

As the number of pieces of apparatus increased the available space became more and more crowded until during the last few years it has been difficult to carry on the work successfully. The steam laboratory had been placed in a comparatively low basement and the moisture and heat produced by the steam made the working conditions very bad.

After careful examination of the whole question, the Board of Governors of the University decided in June 1908 upon the erection of a new building to accommodate the laboratories for steam, gas and hydraulic work and also for all general mechanical engineering, and the building described in this article is the result.

The money appropriated for the building as erected was between $85,000 and $90,000 and for new equipment approximately $22,000, although most of the apparatus which had been installed in the old laboratory has been moved in, so that the total value of the apparatus and equipment in the new building would considerably exceed the $22,000 mentioned above.

New Laboratory.

The building about to be described contains the laboratory for steam and gas engines, steam boilers, refrigerating machinery, belt and oil testing, and other similar work, and also that for hydraulic work of various kinds. It is built of white brick with white stone trimmings and consists of two parts divided by a wall running east and west, the part to the south of this wall having but one floor while the part to the north has three floors.

When the building was first under consideration a number of very difficult problems presented themselves, partly in the way of finding sufficient room in already overcrowded grounds, and partly in the way of making the building harmonize with the other University buildings. In order to carry on the instruction required a boiler room was necessary which had to be placed on the outside of the building in order to facilitate the delivery of coal and the removal of ashes. Then, too there was the problem of stacks, two of which have been provided for experimental purposes, and the necessity of good light and large rooms, so that it was difficult to make the building look attractive.

The architects considered the question with great care and arranged a scheme by which the boiler room and other unattractive parts will be eventually hidden when the entire group of buildings for the Faculty of Applied Science is completed.

The first figure shows the building as it will finally appear. The front will be to the west and it will face on the main University road which runs north from College Street, directly opposite University College. To the north of the building it is proposed in future to run a cross road east from the one above mentioned, the new road separating the Mechanical Laboratories and the building which will in time replace the present Engineering Building. At present there is only a very narrow passage between the two buildings. On the south the building will be connected to the future extensions to the Chemistry and Mining Building, which extensions are to be so planned that almost the entire south side together with the boiler room, which is now exposed, will be hidden.

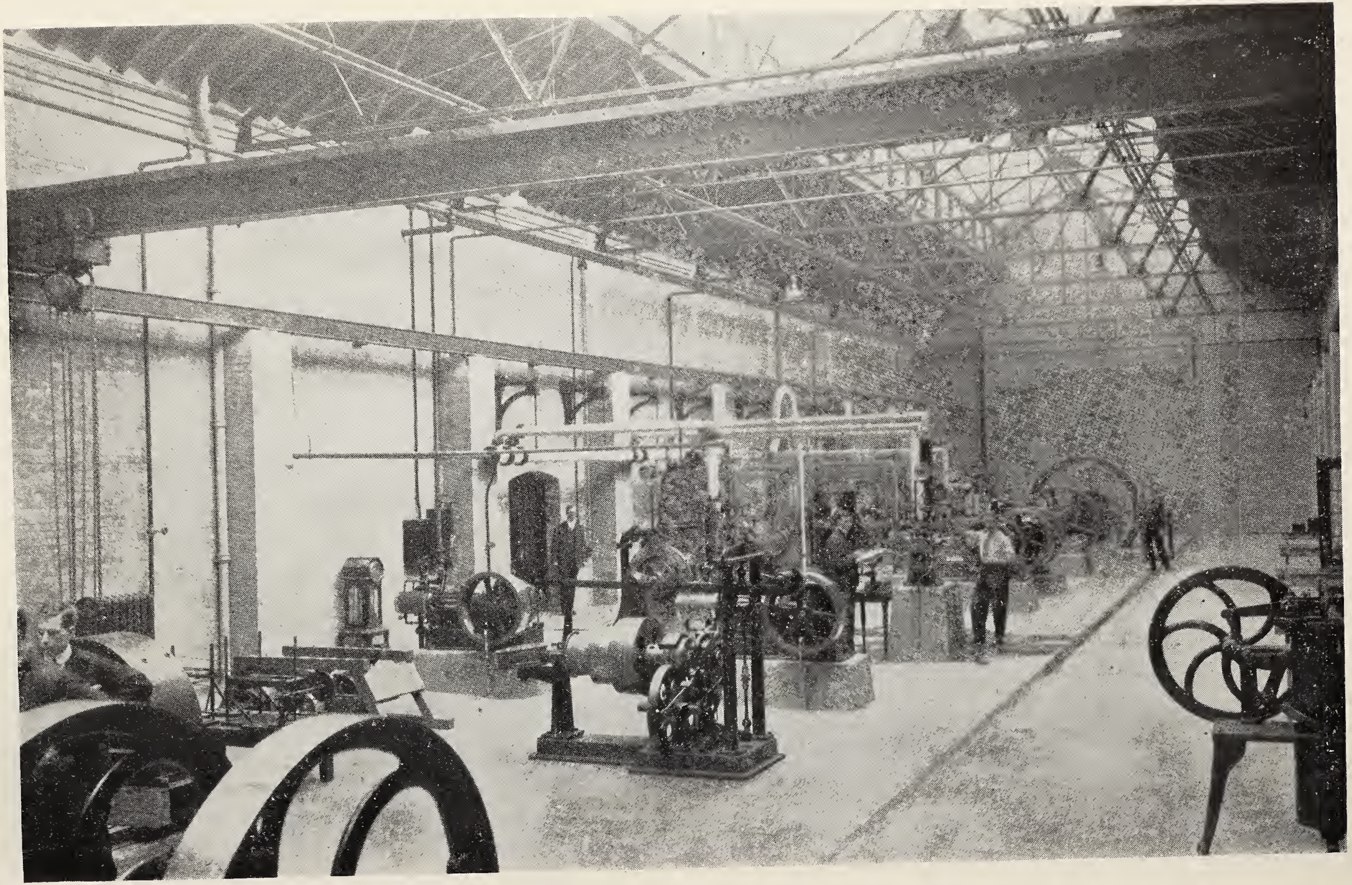
The buildings will thus have a fine appearance and will with the Chemistry and Mining Building form a fine, large block quite in keeping with the nature of the work being done by this Faculty of the University.

Owing to the other pressing needs it was felt by the Board of Governors that it would be impossible to erect the entire building at the present time and as laboratory accommodation had to be provided the part containing this was erected and a reasonable number of class rooms provided in it, while the front part, which will contain more rooms of this nature, has had to be omitted for the present.

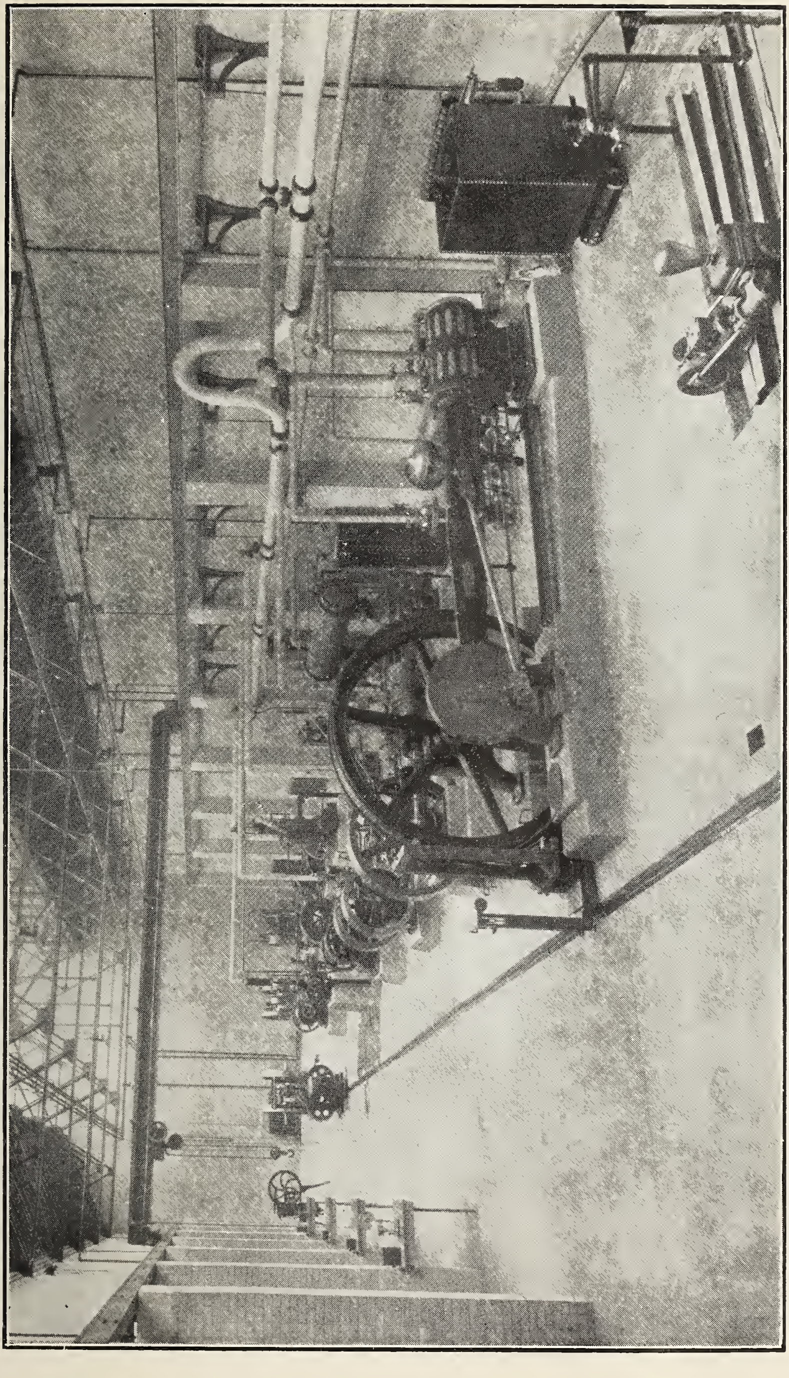
The Thermodynamic Laboratory.

Beginning with the space devoted to the heat engines and general mechanical work, we enter the Thermodynamic Laboratory. This laboratory occupies with the boiler room, the whole south half of the building and exclusive of the latter is 156 ft. long by 60 ft. wide with roof light throughout, there being no windows in any of the walls. It is divided into two parts, one being 40 ft. wide and the other 20 ft. wide, running the entire length of the room. The wider part has a clear height of 23 feet at the sides, being considerably higher in the centre. The narrower part has a clear height of 12 feet, and is divided up into smaller parts, there being eight small rooms, to be described later, and a space for delivery and unpacking of goods. The light is obtained from the roof and is as near perfect as can be expected. The ventilation is also very good, being obtained by opening windows in the roof, a method which works so well that the building can be kept quite cool even with all the machines operating at once.

Internal Combustion Engines. — The equipment in the two parts of this laboratory may now be described in some detail, beginning with that in the larger part. The west end of this



Thermodynamic Laboratory—General View from West End

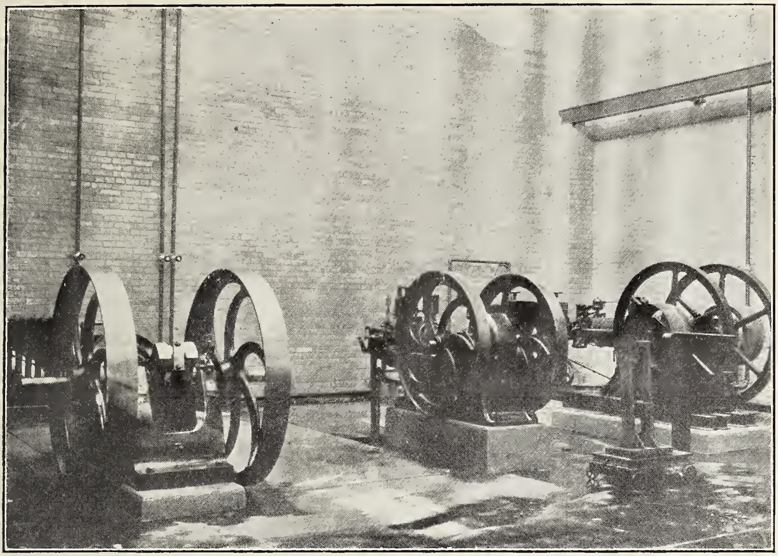


Thermodynamic Laboratory—General View from East End has been devoted to gas, oil, and other internal combustion engines and the equipment consists of a 10 H.P. engine built by Fielding & Platt, of Gloucester, England. This engine has a cylinder 7 in. diameter and 14 in. stroke and has been specially built for experimental work. It is designed for variable compression, so that it may be adapted for use with different classes of fuels; and it is further equipped with three types of igniting gear, viz.: hot tube, high tension electric and a magneto gear, an arrangement being made so that the point of ignition may be varied at will while the machine is running. There is also a convenient method of varying the speed, and the use of heavy fly-wheels prevents great speed fluctuations at different speeds and loads. The engine is also fitted with vaporizing apparatus so that it may be run with oil, and has properly designed valves for the use of suction gas.

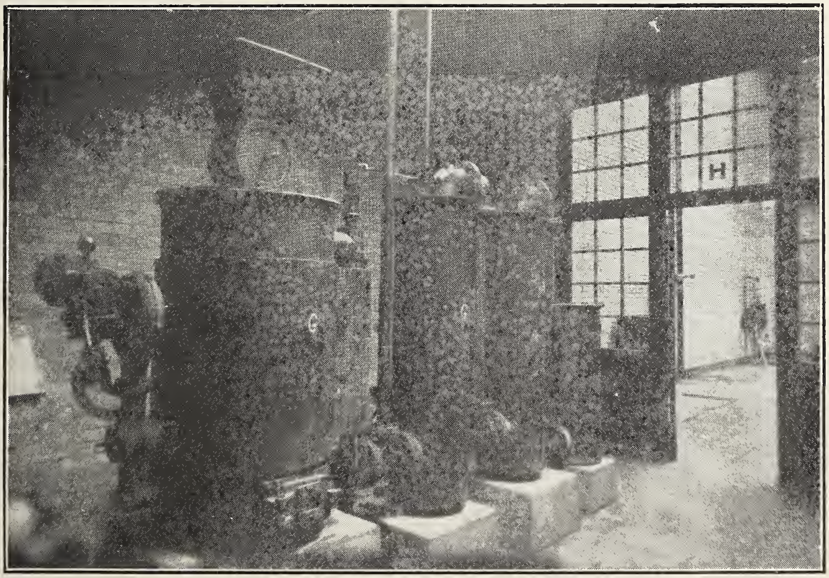
Adjacent to this engine is a larger one built by the National Gas Engine Co., Ashton-under-Lyne, England, and delivered in the building last June. It has a cylinder diameter of 9 in. and runs at a normal speed of 200 revolutions per minute, giving 22 H.P. on city gas. This machine is a very fine sample of a gas engine, being exceptionally heavy and having two massive fly-wheels which give steady speed. It has variable compression as in the case of the Fielding & Platt engine, and is designed for the use of either city or suction gas. It has only the magneto form of igniter, but the point of ignition may be altered without stopping the engine, which is noiseless in operation.

As already explained, both the above engines may be operated by city or suction producer gas. In the former case the gas is drawn directly through a meter where it is measured. When suction gas is used the latter is drawn from a producer in the small room in the south-west corner of the building. This producer, which was built by the Canada Foundry Co. of Toronto, consists of a generator complete with vaporizer, two scrubbers, and an expansion box from which the gas is delivered to a pipe conveying it directly to the engine. It is arranged so that fuel consumption tests may be made with it and the action of the producer carefully and accurately studied.

Adjacent to the Fielding & Platt engine and on the north side of it a test floor has been arranged so that engines of fairly large size may be conveniently tested, and it is hoped that various firms will, from time to time, place some of their engines at the disposal of the laboratory for examination and research work, as it is believed that this will prove of mutual benefit to the manufacturer and the University. This test floor is at present occupied by one of the earliest types of gas engines built by the Otto Gas Engine Co., Philadelphia. The engine has given good service in the engineering building for nearly twenty years and is retained to give some idea of the development of the gas engine of late years and because of its historical interest. It is



Thermodynamic Laboratory—The Gas Engines



Thermodynamic Laboratory—Suction Gas Producer one of the slide valve type of engines with the old form of gas flame igniter, and is in good condition for test and comparison with the newer machines.

The space immediately in front of the engines just mentioned is used for two smaller test floors for gasoline and other similar small engines. Each floor is three feet square and has adjustable slots by which any small engine may be accommodated.

A marine gasoline engine with a cylinder 6 in. diameter and 6 in. stroke has been given by the Canadian Fairbanks Co., Toronto, at a nominal price and has been placed on one of the test floors mentioned and set up for experiments. This engine is to be equipped with an optical indicator made by Dobbie, McInnes & Co., Glasgow, so that its action may be accurately studied.

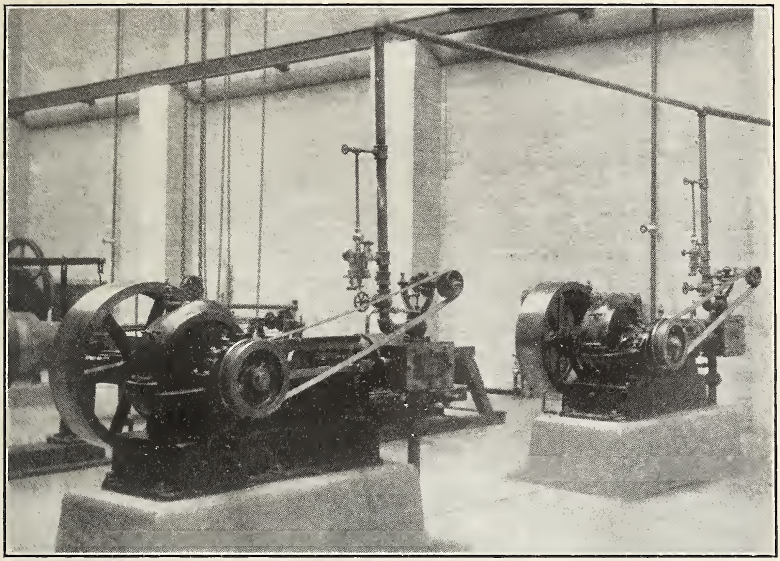
On the south side of the large room is an Ericsson air engine which serves to illustrate the action of this type of engine and to give figures on its economy. It is arranged to be run by city gas and a brake has been arranged to measure the brake horsepower at the same time as the indicator diagrams are taken. The efficiency of the machine as a pumping engine may also be found by allowing it to lift a measured quantity of water against a measured head.

Other Apparatus. — Proceeding farther east along the large room there is seen a fan on which experiments on its efficiency are to be made.

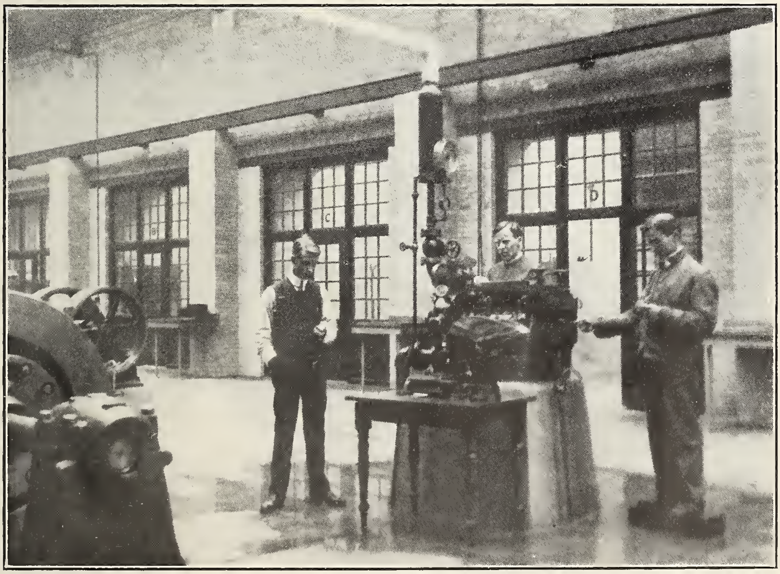
A little farther down is a slide valve model. This model is very complete and has been constructed so as to give results on almost any design of simple slide valve or link motion. The length of connecting rod is adjustable, as well as the angle of advance and throw of all eccentrics, the length of eccentric rods, radius and point of support and suspension of the link, etc.

There is also a journal oil tester built by Riehle Bros. of Philadelphia and having various adjustments. The journal used in the machine is a full sized railway car journal, and the design is such that the actual pressures and speeds occurring in practice may, within limits, be obtained. The friction of the journal is conveniently read off on a scale beam.

The Steam Engines. — We pass on now to the steam engines. The first of these are two of comparatively small size which were presented to the Laboratory by Messrs. E. Leonard & Sons, London, Ontario. These engines are used almost exclusively for exercises in valve setting and have cylinders 6 in. and 7 in. in diameter respectively, and 8 in. stroke, but have different types of slide valves. The one to the south has the ordinary D form of valve and a special design of eccentric by which the angle of advance and the throw of the eccentric may be independently varied. The other engine has a special type of inside admission valve which is partially balanced and so designed that



Thermodynamic Laboratory—Two Leonard Engines for Valve Setting



Thermodynamic Laboratory—De Laval Steam Turbine, Small Rooms in Background the engine may be operated without the steam chest cover and thus show the motion of the valves; this engine has an eccentric of the same type as the one just described.

Both of these engines are fitted with throttling governors and suit the work for which they are designed exceptionally well, the kindness of the donors being much appreciated.

Next to these is a 15 H.P. de Laval steam turbine built by Greenwood & Batley, Leeds, England. As is the case with most of the other machines, this turbine has been specially arranged for experimental work and has six nozzles altogether, some of which are for non-condensing operation and the others are used when running condensing. The rotor of this turbine runs at a speed of about 24,000 revolutions per minute, the power shaft running at one-tenth of this speed. This turbine has been found very useful as an experimental machine.

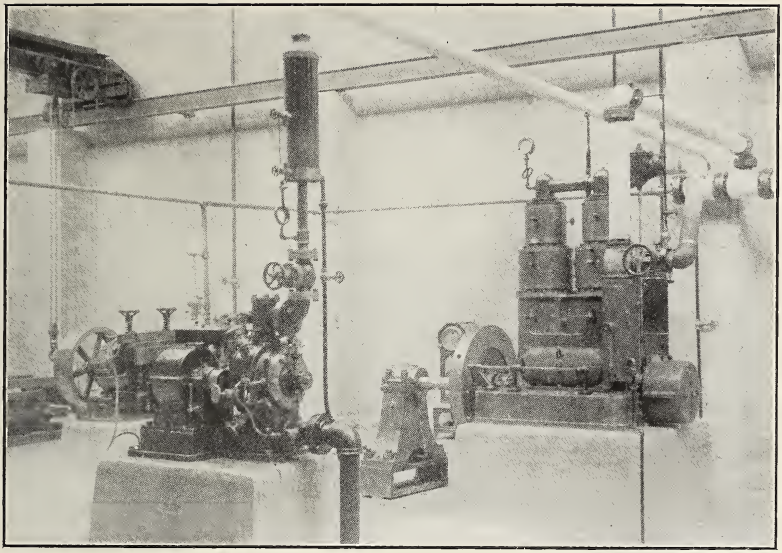
Behind the turbine is a Willans vertical, high-speed compound engine. This machine was purchased to drive the turbine pump in the old laboratory, but with the building of the new one an extra pump had to be installed so that a larger engine had to be purchased to supply the necessary power and the Willans engine became available for experimental work. It is of the high-speed type, having a normal speed of about 460 revolutions per minute, and developing at this speed 75 H.P. with a steam pressure of 125 pounds per square inch.

The design is rather peculiar as there is no valve gear evident externally. The piston rods are hollow and the piston valves are operated by eccentrics forged solid to the crank pin. In this particular engine there are two high pressure and two low pressure cylinders, the high pressure cylinders being above the corresponding low pressure ones; all are single-acting and in order to prevent shock on the crank at the end of the stroke there is an air piston below each pair of cylinders, the pressure of the air compressed by it being sufficient to make a continual downward thrust. The crank bearings have no upper cap and require none for the above reason.

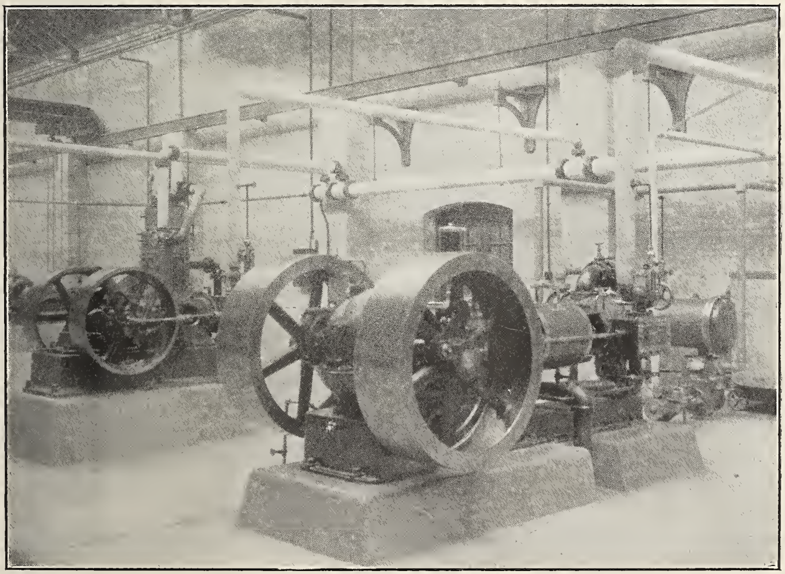
The steam cylinders are respectively 10 in. diameter and 14 in. diameter, and all pistons have a stroke of 6 in.

Engines of this type have met with great favor in England because of the low steam consumption, a paper by Mr. Willians read before the Institution of Civil Engineers in April, 1893, giving some very valuable information along this line.

A passage leading to the door separates these engines from the McEwen high speed horizontal engine. The cylinder is 8 in. diameter and 7 in. stroke, giving 18 H.P. This engine has a good form of shaft governor so that it is well adapted to instruction in the use and action of such governors, as well as providing good indicator practice. As it is connected like the other machines to the surface condenser, tests on the economy of the machine may be conveniently made.



Thermodynamic Laboratory—Steam Turbine and Willians Engine



Thermodynamic Laboratory—Tandem and High Speed Engines, also Surface Condenser

The Leonard-Ball tandem compound engine is also provided with a shaft governor of different type from the one mentioned above. This engine is horizontal and has cylinders 7 in. and 12 in. diameter by 10 in. stroke and will thus develop about 29 H.P. at 250 revolutions per minute.

There are two types of valves in the engine, the one in the high-pressure cylinder being a Ball valve with double inside admission. The valve is partly balanced, gives rapid cut-off, and on account of the double parts has a comparatively small travel. In the low pressure cylinder a balanced D slide valve is used.

This engine provides instruction in the tandem type of machine as well as practice with a shaft governor.

Next to the engine just described is the air compressor, a machine built by the Canadian Rand Drill Co., Sherbrooke, Quebec, and purchased through Mr. Haight of the class of '96 at one-half the actual commercial selling price. This machine is of the cross-compound, steam-driven, two-stage type, having the low pressure air cylinder arranged tandem with and behind the low pressure steam cylinder, and the high pressure steam cylinder in front of the high pressure air cylinder. The steam cylinders are respectively 9 in. and 16 in. diameter, while the air cylinders are 9 in. and 14 in. diameter, all having the same stroke of 12 in.; the normal speed is 160 revolutions per minute and the rated capacity 340 cu. ft. of free air per minute, with a steam pressure of 125 pds. per sq. in.

The fly-wheel is arranged with inside flanges so that a brake may be applied to it, and by disconnecting the air cylinders the whole may be run as a cross compound steam engine. Both steam cylinders are provided with Meyer cut-off gear, giving considerable elasticity.

The low pressure air cylinder has Corliss inlet gear and pressure gauges and thermometers are arranged for experiments of various kinds.

An air receiver is installed and piping runs to the milling building, delivering air when required to drive a rock drill.

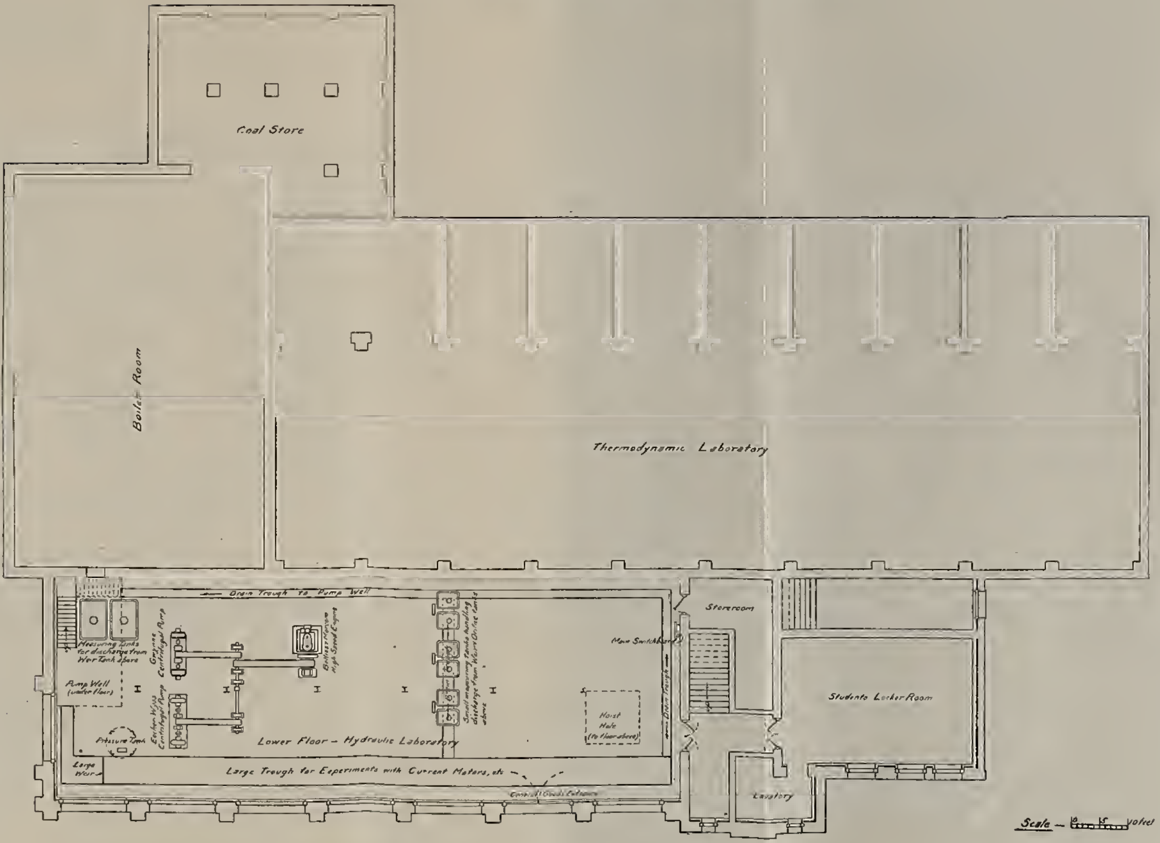
This machine is of great value and usefulness and forms a very good piece of experimental apparatus.

When the Engineering Building was opened it contained a 50 H.P. Brown automatic cut-off engine built by the Polson Iron Works, Toronto, and this engine has been set up again in the new laboratory. It is of special design for experimental work and has jackets on both heads and on the barrel, all jacket drains being separate in order that the condensation in each part may be independently determined. The clearance volumes in this particular machine are also made specially small and it runs quite economically.

The Steam and Exhaust Piping. — An examination of the photographs will show the general arrangement of the steam piping. It consists of a single line of 5-in. pipe running through

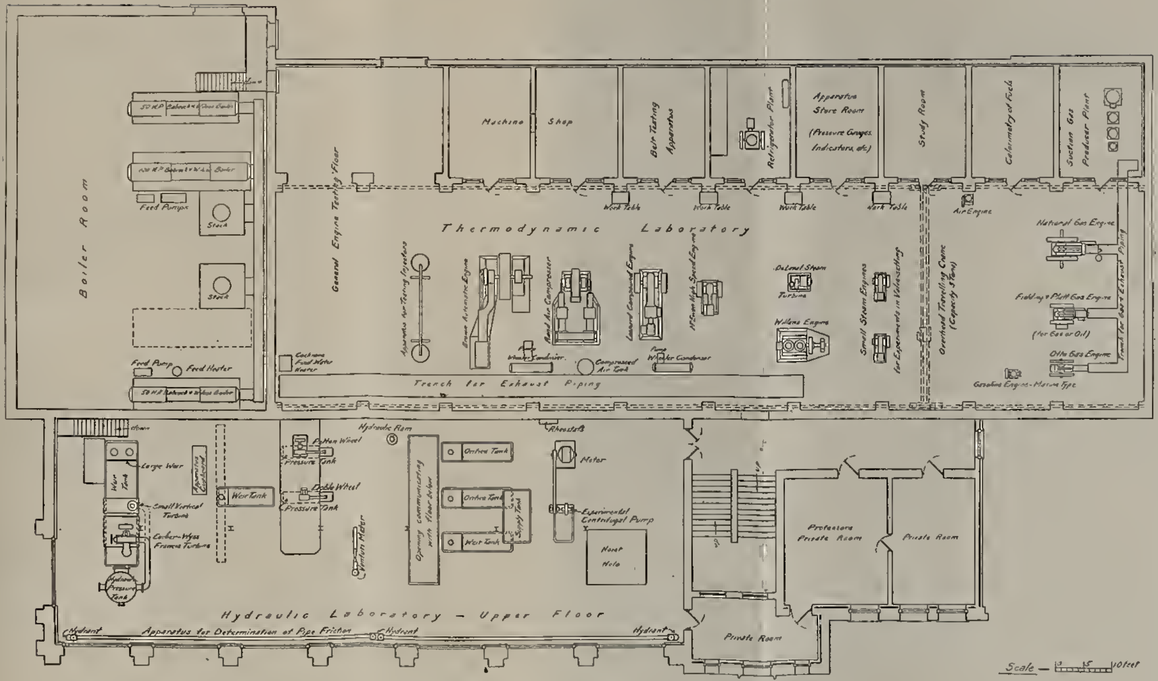
UNIVERSITY OF TORONTO—STEAM, GAS AND HYDRAULIC LABORATORIES

Showing Basement of Hydraulic Laboratory and Foundations of Other Parts


Coal Store
Boiler Room
Thermodynamic Laboratory
← Drain Trough to Pump Well
Measuring Tanks for discharge from Weir Tank above
Gwynne Centrifugal Pump
Bellis & Morcom High Speed Engine
Small measuring tanks handling discharge from Weir Orifice tanks above
Main Switchboard
Pump Well (under floor)
Escher Wyss Centrifugal Pump
Pressure Tank
Lower Floor – Hydraulic Laboratory
Hoist Hole (to floor above)
← Drain Trough →
Large Weir
Large Trough for Experiments with Current Meters, etc
Conical Glands Entrance
Storeroom
Students Locker Room
Lavatory
Scale – 0 15 30 feet

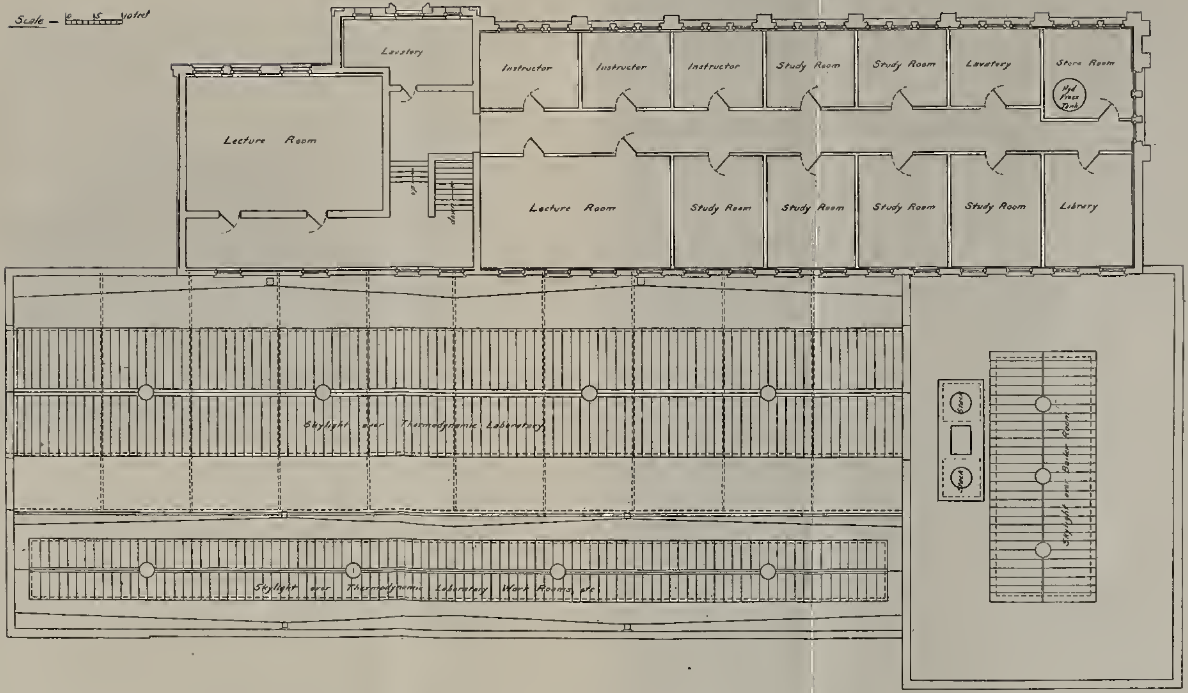
UNIVERSITY OF TORONTO—STEAM, GAS AND HYDRAULIC LABORATORIES

Showing Boiler Room, Thermodynamic Laboratory and Top Floor of Hydraulic Laboratory



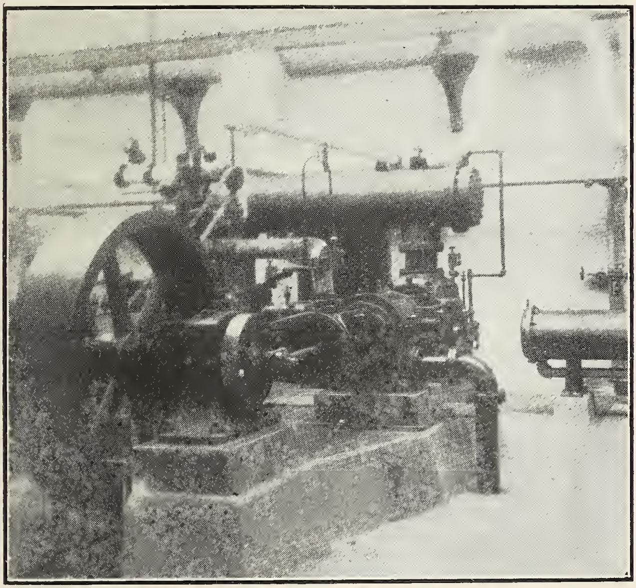
UNIVERSITY OF TORONTO—STEAM, GAS AND HYDRAULIC LABORATORIES

Showing Study and Lecture Rooms over Hydraulic Laboratories



the boiler room and about 90 ft. along the wall of the Thermodynamic Laboratory, also of a 3½-in. pipe running from the northerly boiler up to the Brown engine connection. The latter pipe is designed so that it is possible to run a complete engine and boiler test on the Brown engine and the one 50 H.P. boiler. Connections are also made so that this boiler may deliver steam to the 5-in. pipe and the Brown engine may also be arranged to draw from the same pipe.

The 5-in. pipe has two large expansion bends, the one near the Brown engine being distinctly visible in the photographs. All connections on this line are flanged and each engine draws its supply from the top of the pipe, thus avoiding water from drainage and condensation.



Thermodynamics Laboratory—Air Compressor and Surface Condenser

All engines are arranged to run either condensing or non-condensing, two surface condensers with independent air pumps being installed for the former condition of operation. There are two 6 in. exhaust pipes, one of which is connected to the condensers, the other through the heater to the atmosphere. Both of these are arranged with flanged connections and the system is so designed that by the removal of a few bolts any engine may be changed from the atmospheric exhaust to the condenser in a very short time, it being only necessary to change one blank flange and turn an elbow through 180 deg. The operation is thus accomplished without the use of valves and the measurement of the condensed steam becomes at once accurate. The system also permits the running of almost any pair of engines condensing and at the same time the operation of all the other engines non-condensing. Proper drainage is provided for all piping and it has all given perfect satisfaction up to the present time.

The cooling water piping is shown below the steam piping but possesses no special features.

Brakes. — The writer believes that brakes should be of the simplest form possible so that students get accustomed to the handling of the cheapest and most accessible types. The brakes used are therefore rope brakes or else simple forms of the Prony brake, the wheels being generally provided with inside flanges so as to avoid annoyance from the cooling water.

The remainder of the space in this part contains a test floor which permits any engine submitted for test to be easily set up and run either condensing or non-condensing. There is also a space for the testing of injectors, these being arranged on a convenient and neat pipe stand ready for operation.

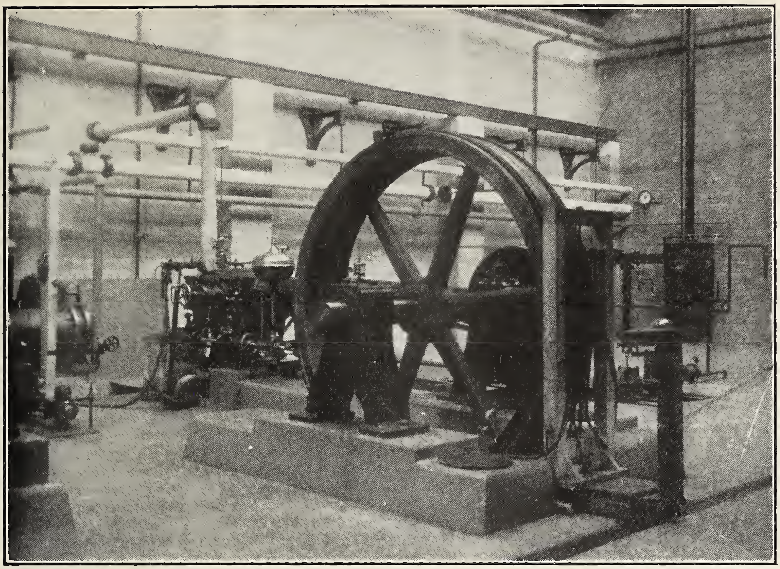
At the end of the room is a Cochrane Feed Water Heater purchased from the Canada Foundry Co., Toronto.

Some space has been left at this end of the room for expansion and it is hoped that in the near future a triple expansion engine will be installed here.

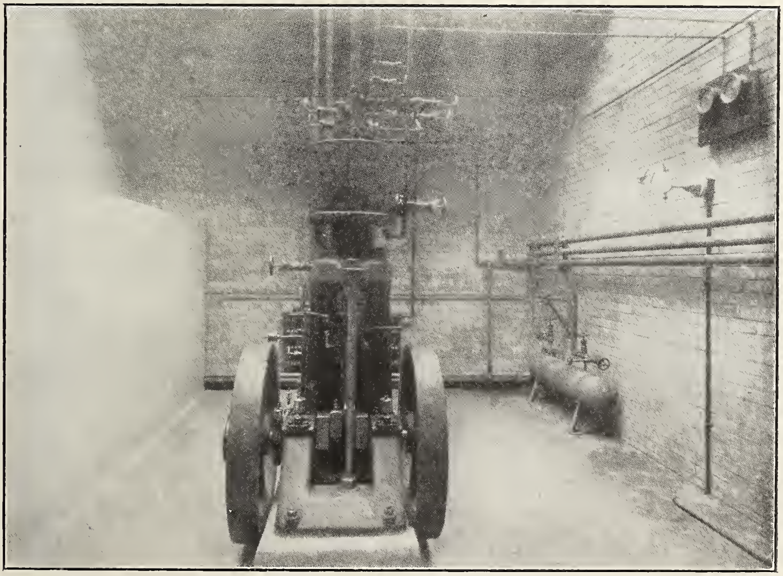
Small Laboratory Rooms. — The narrower southerly portion of the Thermodynamic Laboratory (with the exception of the two end bays which are used for delivery and unpacking) is divided into eight small rooms for special work of various kinds. The first two rooms are connected by a door and are used as a small repair and instrument-making shop, in which special apparatus is made as required. This shop contains a new 20 in. Bertram engine lathe of modern construction built by John Bertram & Sons, Dundas, Ont. There is also a 20-in. McDougall drill, an emery wheel and a wood-turning lathe together with a good equipment of tools. The shop is driven by a Westinghouse motor.

The third room will contain the apparatus for testing various machine elements and the methods of power transmission. For this purpose a torsion dynamometer has been purchased from J. Amsler-Laffon & Sohn, Schaffhausen, Switzerland, which may be used for the transmission of any power not requiring over 540 ft. pds. twisting moment. As the machine may be safely run at high speeds its possibilities in the way of power transmission are fairly great, and it thus serves as a very flexible instrument. This instrument will be used to deliver a measured quantity of power to a belt or rope or any form of bearing or machine element, and the efficiency of the transmission or the element may be directly determined by absorbing the power by a brake at the driven end.

The fourth room contains a refrigerating machine of three



Thermodynamic Laboratory—Brown Engine, with Feed Water Heater in Background



Thermodynamic Laboratory—Refrigerating Machine and Equipment tons capacity, built by the York Manufacturing Co. of York, Pa. It is of the ammonia compression type and the horizontal steam engine and vertical compression machine are connected to the same crank. The complete accessory equipment has been provided and arrangements made for indicating the steam and ammonia cylinders and for taking the temperature at every desirable point in the plant.

The next room has been set apart for instruments and in it are kept all of those used in both the Thermodynamic and Hydraulic Laboratories. All instruments are given out to students on application by ticket and are charged up against the one receiving them. When an instrument is returned it is examined and if in proper condition is put in its place, but if found to have been damaged by the student the cost of repair is charged against him. By this system careless handling or loss of instruments is avoided.

The sixth room is used as a Third Year study room while the seventh is to be used for the testing of lubricating oils and the determination of the heating power of gases and fuels of various types. A Sargeant gas calorimeter has been purchased and is to be used in this room.

The last room is occupied by the suction gas plant, described earlier in this article.

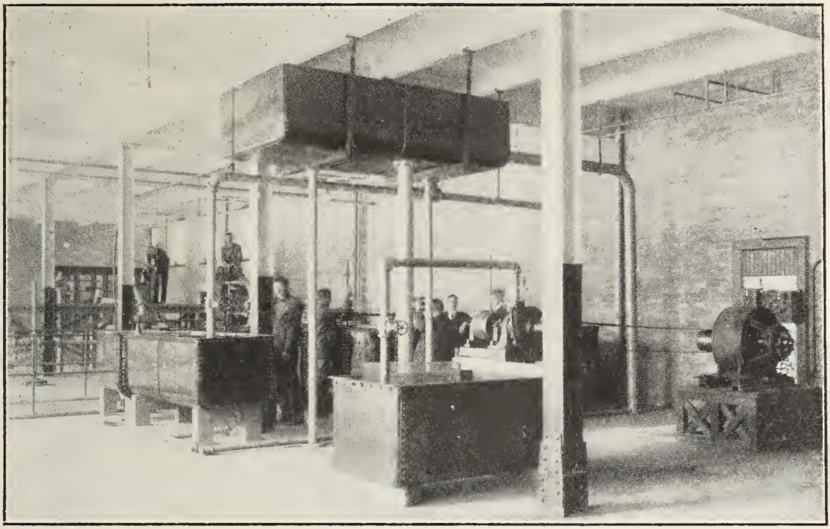
Just in front of these rooms and secured to the crane piers a number of tables have been placed on which work on gauge and indicator calibration may be carried out, the gauge calibration being done by Crosby gauge testers, while the indicator springs are calibrated by means of steam supplied at various pressures.

The whole of the larger part of this laboratory is served by a three-ton travelling crane of about forty feet span. This crane is operated by hand and has proved of inestimable value in the placing and handling of the different pieces of apparatus.

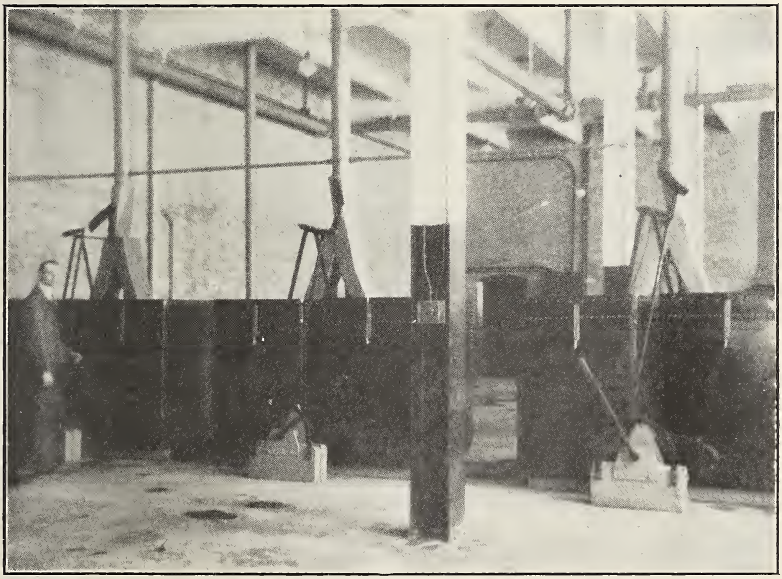
The Hydraulic Laboratory.

The Hydraulic Laboratory occupies the north half of the building and is located in the basement and ground floors, each of which is 40 ft. wide by 113 ft. long. The light for this laboratory had to be obtained from the north and east, and as only one large window could be placed in the east end, the north light had to be depended on almost entirely. Large windows running up the full height of the two laboratory storeys were designed, which take up three-quarters of the entire side of the building. This gives a good architectural effect and while not giving as good light as is obtained from the roof in the Thermodynamic Laboratory, yet it is quite satisfactory.

On account of the large area of glass exposed to the north, trouble was anticipated in the way of heating the building and



Hydraulic Laboratory—General View of West End of Top Floor



Hydraulic Laboratory—Orifice and Weir Calibrating Tanks in Basement arrangements were made to put double windows throughout, which, however, have not been necessary.

The lower storey or basement is 18 ft. high and contains the well, the pumps and the engine for driving them, the measuring tanks used for calibrating the orifices and weirs above, several large troughs and the main part of the piping for the entire laboratory, while the upper floor, which is 15 ft. high, contains the orifice and weir tanks, the experimental centrifugal pump with its weir tank and motor, the various pipes for friction experiments, the meters, and also the various types of turbines and other apparatus.

Beginning with the top floor at the west end, part of the space had to be left clear for a hoist hole, the first piece of apparatus being a centrifugal pump of special construction for experimental work. This pump was designed along theoretical lines and has carefully polished vanes on the runner; it is mounted on a weir tank so that the discharge may be very easily measured, the various heads under which it is operated being obtained by throttling. The pump is driven by a variable speed motor by means of which the power put into the pump may be determined and its efficiency readily obtained. The arrangement has been found very satisfactory as it gives the student an opportunity to study the effect of variations in speed, discharge, pressure and efficiency of the machine.

Adjacent to this are two orifice tanks and a weir tank used mainly for instruction in the use of orifices and weirs. Various sizes and shapes of orifices are inserted and operated under several heads as measured by hook gauge. The water is discharged through 6-in. pipes into the calibrating tanks below, of which there are six, two for each orifice and weir, each tank having a capacity of about 50 cu. ft.

These calibrating tanks are of some interest and have been carefully designed so as to be entirely operated by the movement of a single lever. When the lever is put in one extreme position one tank is made to fill, its outlet valve being closed, while the outlet valve of the other tank is at the same time open. For the small discharges the tank fills so slowly that the upper surface is quite smooth and undisturbed and therefore the exact height of the water in the tank, and consequently the volume of the water at the moment of dumping is easily observed, but where the discharges are large the surface of the water in the calibrating tank is so disturbed that accurate observations of this kind are impossible. To obviate this trouble the mechanism is so designed that by moving the lever to an intermediate position the outlet valve on the other tank is closed and the discharge turned into it, the water surface in the first tank coming to rest at once its height is easily observed, after which the lever is pushed to the other extreme position, the outlet valve of the first tank being thus opened without disturbing the conditions in the second tank.

The quantity of water in the tank after filling may be found by direct weighing or by reading the level in an attached gauge glass.

The floor has been constructed with an opening protected by a rail, so that the student may observe the whole operation at one time and thus get a clear idea of the process of calibration.

In order that experiments on these tanks and orifices may be carried on without interfering with the other work, a large reservoir, provided with an overflow, has been placed above them, and from this they draw water. So long as there is enough water passing into the reservoir to cause some overflow the experiments may be carried on at various heads and discharges without difficulty.

From this reservoir a 1¼-inch pipe is also run to a hydraulic ram which can thus be operated under a head of about 10 ft. and with a drive pipe about 40 ft. long.

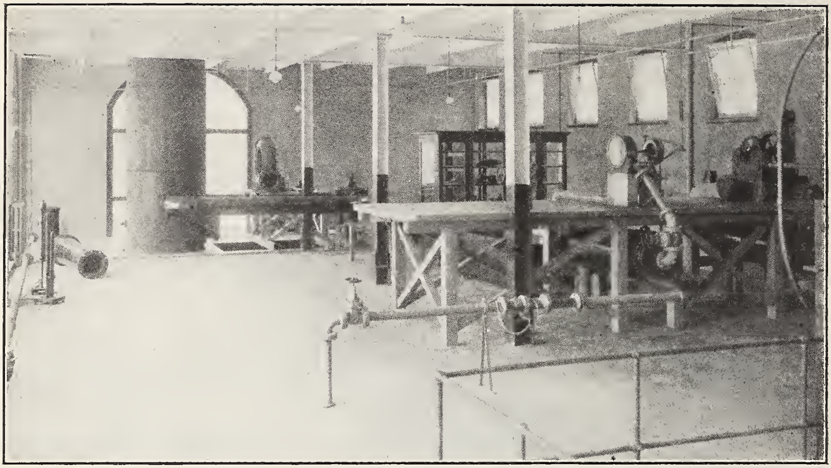
A three-inch Venturi meter has been installed on a pipe in which other meters will also be placed. This meter is rated by sending the discharge from it through one of the orifice tanks already described, using the coefficients determined by actual experiment.

A little to the east of the centre of the laboratory an elevated platform about 25 ft. long and 7 ft. wide has been erected for the impulse turbines. At present two turbines are in use, one a Doble wheel made by the John McDougall Caledonian Iron Works, Montreal. This is a very well finished wheel of 12 in. dia., and as it has glass sides the action of the water may be very conveniently studied. The needle regulating nozzle gives a very perfect stream.

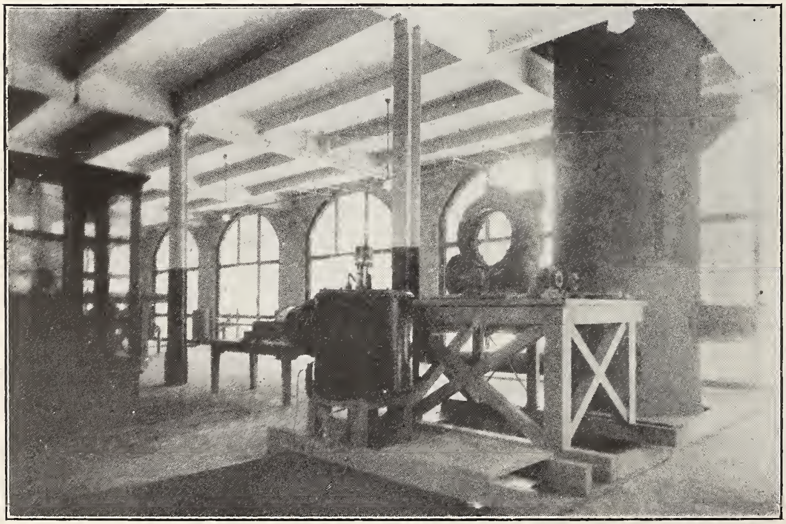
The other machine is an 18-in. wheel made by the Pelton Water Wheel Co., and although not so well constructed, it represents a very common class of water-wheels in use to-day.

The water used by these turbines is measured by passing it through a weir tank and then back to the pump well. For the use of these turbines it is possible to get a discharge of 1 cu. ft. per sec. against a maximum head of about 500 ft.

At the east end of the room is a large stand-pipe 32 ft. high and 5½ ft. dia., supported on a stand in the basement so that it reaches up into the roof of the building. This stand-pipe is used as a reservoir for the reaction turbines and also for any experiments requiring constant but not very high heads. This stand-pipe has a 14-in. nozzle on each side for the attachment of turbines and also a large nozzle 30 in. dia. on the front so arranged that orifice plates and tubes of various sizes may be attached and experiments made at higher heads than is possible in the open orifice tank. The water is delivered to the stand-pipe through two 8-in. pipes near the bottom and by a convenient arrangement of baffle plates there is no trouble caused by the surging or eddying of the water.



Hydraulic Laboratory—General View of East End of Top Floor



Hydraulic Laboratory—Top Floor Showing Reaction Turbines, with Weir Tank and Reservoir

In front of this stand-pipe is a large weir tank 20 ft. long by 6 ft. wide, which is arranged with a sharp crested weir 4½ ft. wide with end contractions. This plate may, however, be changed so that weirs of different sizes, with or without end contractions, may be easily inserted. The total depth of the tank is 3 ft. 9 in. and the depth of water below the crest of the weir is 2 ft. 3 in.

The weirs used in this tank may also be calibrated by means of a pair of measuring tanks in the basement, each holding approximately 240 cu. ft. and both being connected to the weir tank on the down stream side of the weir by 12-in. galvanized iron pipes. Hydraulically operated valves are to be used in connection with these calibrating tanks and are so designed that a single lever is made to do the whole operation of filling and emptying as in the case of the smaller tanks already described. This lever, as in the former case, has three positions when operating, the extreme positions indicating that one tank is filling and the other emptying, while the intermediate position is used when both discharge valves from the tanks are closed and one of the tanks is filling. It is believed that very accurate coefficients can be determined by this method.

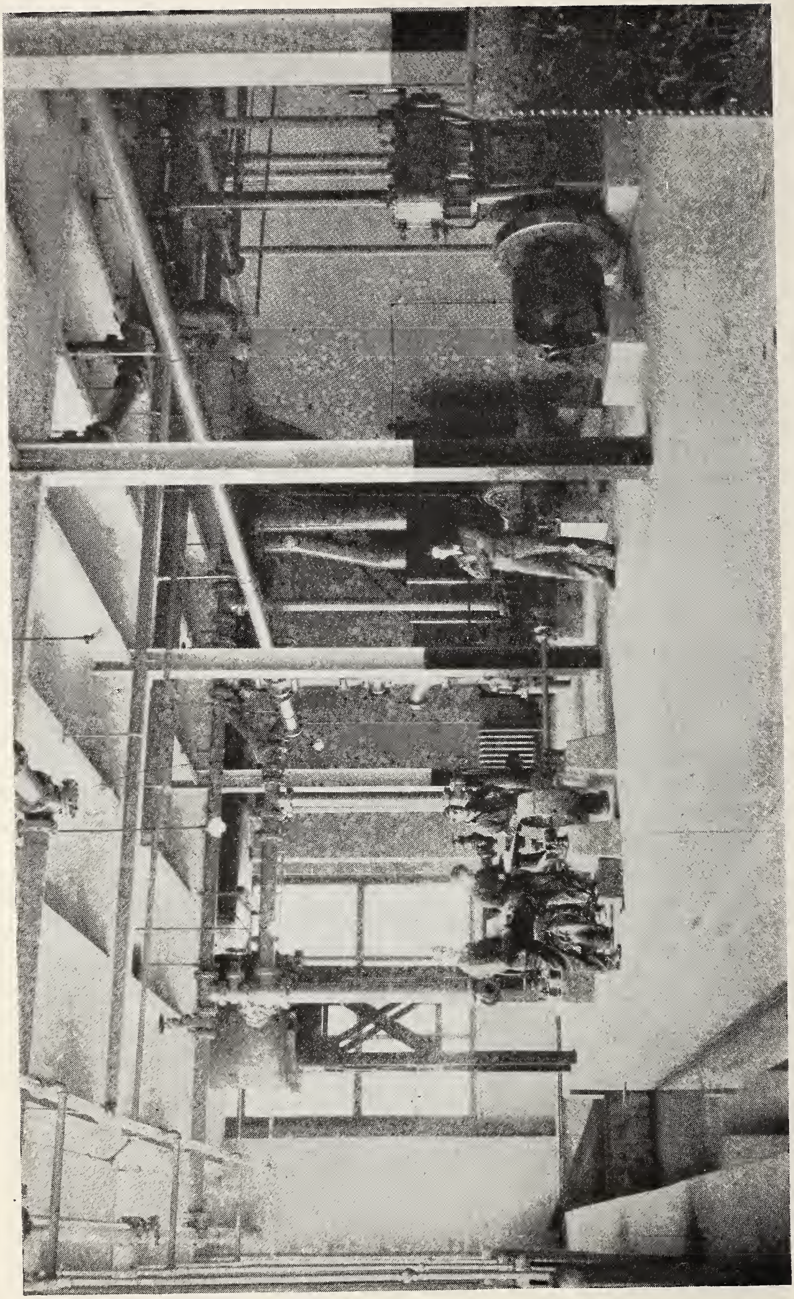
There are three reaction turbines available for testing. The smallest one has a 6-in. runner and was made by Wm. Kennedy & Sons, Owen Sound, Ont. It has been set up in a steel penstock and connected to the stand-pipe by a 14-in. steel pipe containing two elbows. This pipe is to be used for experiments on the flow through elbows, the conditions being examined by a Pitot tube. This 6-in. turbine has been operated under a total head of over 25 ft., including about 5 ft. in the draft tube. The horse-power is measured by Prony brake and the discharge is determined from the 4½ ft. weir.

A 9-in. McCormick turbine with cylinder gate has not been set up but is left to give the student practice in the measurement of such wheels and to enable him to study the forms of the vanes.

The latest turbine to be installed is one purchased recently from the noted hydraulic firm of Escher, Wyss & Co., Zurich, Switzerland. This wheel, of the horizontal Francis type, has a well designed spiral casing and a runner nearly 14 in. dia. The gates are of standard design, operated through a ring by a hand wheel on the casing. A conical draft tube over 7 ft. long is used and the wheel will deliver 10 H.P. when supplied with 6 cu. ft. of water per sec. at a head of 20 ft. As this wheel is of the very best construction it forms an excellent addition to the experimental equipment.

The maximum quantity of water available for these reaction wheels is about 6 cu. ft. per sec.

Along the north side of this floor near the windows arrangements are made for the testing of the friction in fire hose and iron

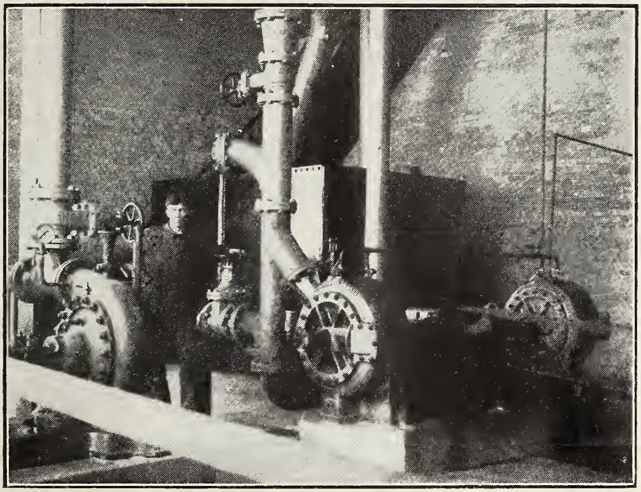


Hydraulic Laboratory—General View in Basement Showing Open Trough, Pumping Units, Engine, Etc.

pipe. A 2½ in. iron pipe 50 ft. long has been set up, also a 50 ft. length of fire hose, and the frictional losses are determined. The flow in the iron pipe is also studied by the Pitot tube, and curves showing the distribution of the velocity are plotted.

The basement contains, in addition to the orifice and weir calibrating tanks already mentioned, the well and pumping plant. All water used in the laboratory is drained back to a large well from which it is pumped into the system and used over and over again.

There are two sets of turbine pumps used for this purpose, one of which was built by Messrs. Gwynne, London, England, and the other by Escher, Wyss & Co., Zurich. Each set consists of two two-stage pumps fastened to a common bed plate and driven by a single pulley, couplings being arranged so that either pump may be separately operated. Further, the two pumps on the one base are piped together in such a way that they may be made to deliver into the piping in three ways, viz., (a) separately, (b) in series, (c) in parallel. A connection is also designed to connect the discharge from the Gwynne pump to the suction from the Escher-Wyss pump, putting the two sets in series for very high pressure work.

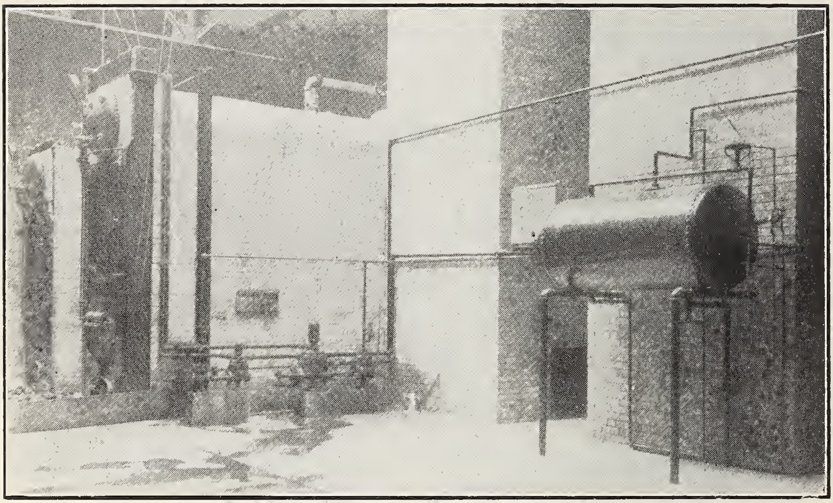


Hydraulic Laboratory—The Two Pumping Units

Each of the Gwynne pumps will deliver 1 cu. ft. per sec. against 125 ft. head, while the other pumps have the same capacity against 150 ft. head, the discharge at lower heads being, of course, much greater.

As suitable piping has been arranged in the laboratory, it may thus be seen that the whole arrangement of the plant is very flexible, permitting (a) the operation of the four pumps separately, thus allowing four absolutely independent experiments at one time; (b) the operation of the two sets separately on separate experiments; (c) the operation of the two sets in series for high pressures and moderate discharges as are required in fire streams and impulse turbines, giving 1 cu. ft. per sec. at 500 ft. head; (d) the operation of the two sets in parallel giving about 6 cu. ft. per sec. at the heads available in reaction turbine work in the laboratory.

The pumps are of modern design, the Escher-Wyss set having been installed during the fall. They run at speeds of 1,300 and 1,400 revs. per min. respectively, and are belt-driven from a jack shaft placed on the floor, vibration of the building being thus entirely avoided. The jack shaft is driven by a Belliss Morcom engine of 130 H.P. running at 530 revs. per min. This engine is a very fine piece of workmanship and runs quietly and without vibration. The exhaust from the engine is used to heat the building.



Boiler Room—Only Two Boilers and Two Stacks Shown

Arrangements are being made for the insertion of a transmission dynamometer in the Escher-Wyss pump drive so that its efficiency may be determined with greater accuracy than can be obtained by indicating the engine.

A large trough 6 ft. wide, 4 ft. deep and 110 ft. long has been provided in the basement which is used for the rating of current meters and tubes and other work of this nature. It is believed that this will be especially useful in view of the rapid power development going on in Canada at the present time.

There is sufficient space still left for further expansion.

The Boiler Room.

This room contains three Babcock and Wilcox boilers, all built for 200 pds. pressure.

The 100 H.P. boiler is provided with a superheater while the two 50 H.P. boilers have been set up independently and one is arranged with a special type of setting so that valuable comparative results may be obtained.

A separate feed pump is provided for each boiler so that separate tests may be made on each one.

A steel breeching conducts the products of combustion to the stacks, of which there are two of brick, each 100 ft. high and 36 in. internal diameter. An arrangement of dampers allows these stacks to be operated at different powers on the same day and thus reliable experiments may be made on the capacity of each stack.

The room is light and airy, being 70 ft. long, 45 ft. wide and 26 ft. clear height. All the light is obtained from the roof and is very satisfactory indeed.

Offices and Study Rooms.

An examination of the accompanying plans will show that at the north-west corner of the building, immediately west of the Hydraulic Laboratory, there is a further space partly occupied by the stairways and halls and partly by other rooms. These rooms are as follows: In the basement, the students' room with shower bath, on the first floor the professor's and the lecturers' rooms while the top floor is occupied by a lecture room and private lavatory.

An entire floor above the Hydraulic Laboratory is divided up into students' study rooms, a lecture room, a library, demonstrators' rooms, and students' lavatory. All of these rooms are comfortable and bright and the students' rooms are provided with convenient tables and a locked drawer for each person.

Artificial Lighting.

The large Thermodynamic Laboratory is lighted by ten Nernst lamps, which are attached to the trusses and provide sufficiently good light to do any work required. The Hydraulic Laboratory is lighted by tungsten lamps, there being ten to each floor.

The remainder of the building, with the exception of the boiler room, which also has a Nernst lamp as well as incandescent lamps, is lighted entirely by incandescent lamps, which seem to give very good satisfaction so far.

Conclusion.

This article would be incomplete without making mention of the work of Dean Galbraith. It was he who gave the writer his first real insight into the profession which he honors and it is on the foundation laid by him that the writer has built in striving to design a laboratory that shall give the future engineers the proper basic principles on which their life work depends. The teaching of principles is vastly more important than the teaching of a few facts, the desire to teach these principles in such a way as to make the practical application clear is a thing for which Dean Galbraith has always stood, and the writer's association with him and with the engineering world have given him the desire to make the laboratories described such as shall be a real help to the student when he gets into active practice.

Acknowledgment is also made of the help given by the members of the staff in Thermodynamics and Hydraulics who assisted by many suggestions and by the sacrifice of much time in making the building and equipment such as it is.

It will be noticed that all of the units in the two laboratories are comparatively small and are such as can be handled with comparative ease. The writer believes this to be a valuable feature of such a laboratory, as the student can readily comprehend the whole machine at one time, and therefore does not lose the connection between the different observations as he is apt to do with the larger units where the parts are so much separated. The results obtained are, the writer believes, quite as valuable, from the point of view of the instruction to the student, when obtained from reasonably small machines as from very large ones.

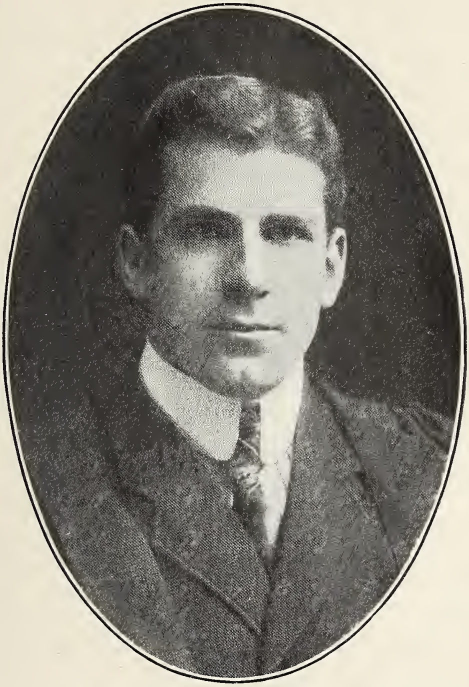
No machine in the laboratory is used for electric power or for any other than experimental purposes, so that all pieces of apparatus are always available for experiment or research.

THE ANNUAL DINNER.

Convocation Hall, January 19th, 1910

The one social event of the Engineering Faculty is the annual dinner of the Engineering Society. It is always looked forward to with considerable pleasant anticipation, and thanks to good management and enthusiasm, is always looked back to with considerable pride. Each succeeding president of the society and his executive have strenuously endeavored to make their annual dinner just a little better than its predecessor. This year their efforts were again crowned with success.

The dinner has always been used as a medium of connection between the University and the commercial world. Last year advantage was taken of the fact that the Canadian Society of Civil Engineers were meeting in convention in Toronto. They were invited to be the guests of the Society and to the number of two hundred attended.



W. D. Black, President of Engineering Society

This year one question which looms large in the field of commerce is industrial education. In the world of commerce the race for supremacy is each year becoming keener. The weak are being constantly pushed to the wall. The raw materials are becoming scarcer, and conservation, the making the most of all resources, is the watchword. Germany has long recognized the old maxim that in knowledge is strength and now it is generally recognized that industrial success must in a great measure depend on technical education. Canadian interests have at length awakened to the need of advancement along the lines of industrial education.

There has been and is still a lamentable lack of intercourse between the Canadian industrial corporations and the universities. It would be interesting to know the reasons for this. Does it lie in the conservatism of the manufacturer, or in the inefficiency of our graduates? Assuredly not the latter, for our men go across the line and hold their own with the best. In all departments but mechanical and electrical, our graduates are being readily absorbed in the development of the country, but in these two, the men are drifting to the United States and are a serious economic waste to Canada. Some Canadian industries, it is true, are using a large number of our graduates, but these are in most cases Canadian branches of American corporations.

With a view of interesting the captains of industry more intimately in the university, and to gain their sympathetic and active co-operation in the solution of the problems of technical education, it was thought advisable this year to invite the members of the Canadian Manufacturers' Association to be the guests of the Society at their twenty-first annual dinner on Wednesday evening, January 19th.

The dinner was a complete success from all standpoints. The undergraduates were at their best, lively with song and jest in their contributions to the programme, but strictly attentive to the various addresses.

The guests from the Canadian Manufacturers' Association, together with the graduates, numbered about two hundred. The student body swelled the attendance to seven hundred.

W. D. Black, president of the Engineering Society, occupied the chair. In a brief speech he welcomed the guests of the evening and proposed the toast, "The King," which was received with an enthusiasm characteristic of School men.

The toast to "Canada and the Empire" was introduced by A. G. McLeish, who after giving voice to the loyal sentiments and aspirations of the students, called upon J. A. MacDonald, LL.D., to respond. Dr. MacDonald spoke as follows:

J. A. Macdonald, LL.D.—

My purpose to-night in responding to your toast is very simple. Representing as you do the trained intelligence of the University, devoted as you are to the application of the great sciences to the great arts, and having as your guests so many men of prominence and leadership in the great industries of this country, I make no apology for venturing a few words of warning against evils and abuses which must be taken out of the way or Canada will never come to its own, and the Empire will not remain united and strong. My warning is against the waste, the disastrous and wicked waste, which has marked centuries of Britain's history, and which, unless the warning is heeded in time, will do irreparable damage to Canadian interests.

(1) I speak first of economic waste alike in Canada and in Britain. Take the outstanding British instance. The great source of wealth is land. Out of the earth and the products of the earth comes the wealth of the people. Food and clothing and all the sustaining and comforting necessities of life depend directly or indirectly on the uses of the country's natural resources. The roots of all great enterprises and institutions are in the soil. But see what happened in Britain. God made the land for the people, but the people were not wise or were not wisely led, and now it is asserted that eighty per cent. of all the land of Britain is held by three per cent. of the people. One-quarter of all the land of Scotland is owned by twelve persons. One man owns in Scotland alone 1,300,000 acres.

But the economic waste is not so much in the limited ownership of the land as in its non-productive uses. Literally millions upon millions of acres suitable for agriculture are declared by competent and responsible authority to have been turned over to the sports of the few. That situation has become worse, instead of better, as the population of Britain has increased. Within one certain period of five years 700,000 acres of moor and bog-land in Germany were reclaimed and put to agricultural uses. Within the same five years 2,000,000 acres in Britain were withdrawn from agriculture and devoted to grass and deer forests. How can a country hold its own with such deliberate and wilful waste of its chief source of economic wealth?

J. A. Macdonald, LL.D.

But has Canada the right to boast? We know how things look in the United States. We know something of the colossal theft and graft that have already cost the people of the United States the control of their natural wealth in land and mine and forest and sea. If Mr. Pinchot's dismissal by the Executive at Washington leads to a complete exposure he will not have been sacrificed in vain. But if we knew all the facts of the

Canadian situation we might find cause for alarm. Certain it is that all over this country the resources and opportunities of public wealth have been alienated to private monopoly. Mineral lands, forest areas, fishing rights, water powers—all these have been coveted and many of them have been captured by private individuals on terms unjust as those that governered the granting of great areas of Britain to favorites of the court. Had it not been for the protests, chiefly of the press, every volt of electric energy of Niagara Falls would long ago have been controlled by some private electric trust or merger. Unless there is eternal vigilence on the part of the public and in Parliament the economic advantages of Canada will yet be largely conducive to private wealth at the expense of public service.

For this reason the very greatest public interests are involved in the work of the Commission on the Conservation of Canadian Resources now in session at Ottawa. In all such work of creating sound and active public opinion in this subject of economic conservation and waste this society and this university, and the various industries represented here to-night, should have a large and influential share.

(2) A second word of warning is against the social waste which has marked Britain's life for centuries. Social waste is an inevitable resultant of economic waste. If a few men control the great sources of wealth and the means of wealth, it must be at the expense of the many who have no adequate chance. The crowding of the people off the land into the towns and cities helped to create and to continue and to aggravate social degeneration and decay. The situation in British cities with their landless people is the correlative of the situation in the rural communities with their vast areas of peopleless land. There is no problem pressing more urgently for solution in Britain than does the problem of checking and curing this appalling waste of workers through social decay.

The same problem presses in Canada. There are everywhere, in every community, the physically and mentally unfit and inefficient. Poor blood, unsteady nerves, untrained minds, low and debilitating instincts—all these factors enter into the problem of a nation's strength. They make for that waste which saps the strength of society. In Britain the appalling drink habits of the people, the craze for sport and their mania for gambling, are causes of which Parliament at last begins to take account. The same problem is important in Canada. If it is neglected similar causes will produce similar results.

(3) My third warning is against the industrial waste which, if unchecked, must result in industrial defeat. Efficiency is the cry in the great centres of successful manufacture and trade. But in Britain to far too great a degree the economic waste and the social waste have resulted in serious industrial waste. In many respects the British manufacturer commands the world's admiration, but all students of British conditions see the enor-

mous wastage which long ago would have brought economic ruin but for those other masterful qualities of the British people which have made them the merchants of the world.

And here again Canada needs to be warned. Our almost unequalled resources in raw materials tempt us to be neglectful. In many industries the rights of labor and the conditions of labor are neglected. The standard and quality of labor too often are inadequate. Germany is awake to the importance of the best technical knowledge and the finest mechanical skill in her industrial enterprises. The United States spend lavishly on the training of their industrial workers. But both Britain and Canada have been slow to harness knowledge to their wheels of industry.

A beginning has been made, a splendid and hopeful beginning. Behind all the political confusion in Britain, which fills the air with dust and clamor, there is a deep and determined resolve to revise and to rationalize the education and training of those who are to man the mills and factories and workshops of Britain. If that resolve is carried out along large lines and with the Englishman's thoroughness, my word for it in twenty years, under favorable conditions, British factories and mills will more than hold their own against all foreign competition. British commerce will command the world's markets, and Britain herself will still be mistress of the seas.

In this new era Canada must play a great and determining part. Here is where the knowledge of laboratories and the skill of the schools are needed. With these vast resources conserved by law, the manufacturers of Canada should hold their own against the world. All they need is trained intelligence and vision in their management and the service and skill of the universities and technical schools in the workshops.

This is the call to this University. It is the call of Canada and the Empire. It is the call to fitness for Canada's great future—fitness in manhood, in knowledge, in purpose. You men of this University, it is on you and with men like you the destiny of your country hangs. Fit yourself for it. The Genius of Canada call to you. By your power and devotion to your plain duty you will help Canada stand with the Empire, one and undivided, and that one will become a thousand, that small one a strong nation, in the great day of crisis and of destiny.

On rising to respond to the toast, "The University," which had been proposed by E. R. Gray, the president, R. A. Falconer, received a most flattering reception, a reception which in a slight measure evinced to the guests the hold he has on the undergraduates of the university. Dr. Falconer said in part:

President Falconer:—

It is not an easy task to speak after such a reception as this, but I assume it is an expression of the unity of this university and the way we are seeking in each of the faculties one common

Twenty-First Annual Dinner, University of Toronto Engineering Society end: to prove to the people at large that what they are doing for us is being appreciated, that expenditures are being wisely made, and that, instead of being wasted, the money we are spending is an investment of the highest order and of the greatest use to the country. The gentlemen from the Canadian Manufacturers' Association, and other leading and prominent gentlemen, have thrown their lives into this Dominion, and into this province, and I feel it is perfectly proper that the captains of industry who have shown their ability in practical affairs should realize what the university means to them. We should get encouragement from them in the work we are doing.

We hear a great deal about the conservation of our natural resources. We are told that unless we are careful in the management of these resources we shall, in the future, reap a sorry harvest. But, gentlemen, I believe there is nowhere that this lesson should be more emphasized than in the university, where we are training men who should go out and assist in the development of these resources. I am told that in Canada we have limitless natural wealth, that our water powers have not yet been measured, that our forests have illimitable supplies. What is the value of these resources? Resources are no resources until they are converted into use for men and women. The resources do not mean resources until human intellect has been applied to them. Gold is nothing as it lies hidden. Water power is of no use to humanity unless developed. These things are practically nothing apart from the men who fling themselves into their development. How can you reduce your ores? Is it by the chance laborer? Not so. It is by men trained to use a method. It is by the mining engineer who knows where to look for resources. It is by the electrical engineer who knows how to convert resources and by the mechanical and civil engineers who know how to construct. Further, it is reasonable in view of the cry of the daily press relative to the conservation of natural resources that this faculty should have gentlemen who realize the situation. The commission at work has its purposes—to hold investigations, to institute research work and to disseminate knowledge. Abstract thought is taught in the universities, but it works itself out in practical applications.

Men are greater than the land in which they work. The man who discovers a mine is greater than the pile of ore which, under his supervision, is heaped up.

The university has something to say with regard to immigration. We are face to face all through this country with the problem of labor. There are multitudes of people coming to this country from the old lands, with old ideas, old prejudices, old hatreds and old social conditions to which they are accustomed. And just as you study the natural resources and their conservation, you must study these resources that are living and vital. Where are they to be studied? In the university, I hope. In the universities we must turn out men who are acquainted with the way the world has run its course, men who know how others have struggled. Further, gentlemen, we can justify ourselves as a university to the men interested in the welfare of this country. The students are the ones who are to justify to this province the position of this university. The country will look to you to understand what is being done here. They will expect of you, in your own localities, wherever you are located, to prove that the money spent in the university is well spent, that the work done is worth doing, and that we are able to produce results that count. You are the ones to explain what the university means. These gentlemen of ability and intelligence realize it.

A. D. Campbell, in proposing "Canadian Industries," indicated the relation of the university to the various industrial activities. He coupled with the toast the names of Louis Simpson, J. P. Murray and P. W. Ellis, three gentlemen representing as many phases of industrial enterprises. Mr. Simpson dealt with the recent progress made in the uses of electricity in smelting and the economic wealth resulting from the electric treatment of otherwise valueless ores. He pointed out that it is now nine years since the Dominion Government sent a commission to Europe to gather facts relating to the reduction of iron ores by electricity.

This commission is known all over the world as Dr. Haanel's Commission. The furnaces then in use were not suitable for the reduction of Canadian iron ores; but in the last year a furnace has been produced which is considered to be entirely commercially practicable. The product of these furnaces might be called a new metal, being intermediate in quality between steel and pig iron, while the cost of production is relatively the same as that of pig iron. Mr. Simpson also argued for the better industrial education of the farmers, and urged that the foundations be well laid in the public schools.

Mr. Murray, who has given considerable thought to the problem of industrial education, followed, Mr. Murray arguing for a broader technical education.

J. P. Murray:—

When we turn to the question of education, we admit that each child is not only entitled to the use of a school but we have enacted laws compelling his attendance therein. How far then are we to go with him in education? By what we are doing and in the doing of it, we acknowledge an obligation and at the same time we accept the responsibility of the obligation. We do in the province as is done in every town, big or little; i.e., tax the people for a school. In the town it is just a "school," but in the province it is a "university." Every boy in the town must attend the school, but only a favored wealthy few may attend the University, though all contribute to its support.

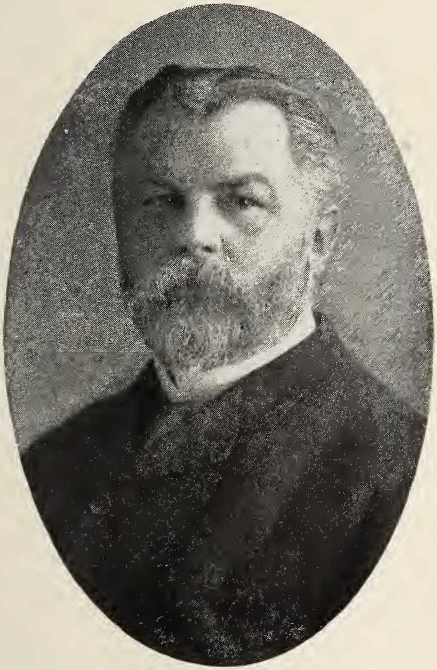
So far there is a marked evidence of favoring the wealthy, or in other words, admitting that one class of the people has privileges over another. This is not the only instance of evidence that may be offered where a favored branch of the community has advantages over another branch. The farmers of the province not only have agricultural colleges to attend, but the professor in cheese and butter-making, etc., actually comes to his door.

The country youth who has ambitions for some sphere of life and activity other than that of the farmer, but who has not the good fortune to be born of wealthy parents, must be satisfied to plod along as an assistant to the village mill-wright and blacksmith, or as an employe of the woollen, grist or lumber mill of his locality. He has, of course, the opportunity—if he knows about it—to contribute to one of the correspondence schools and by the amount of money he sends out of the country, prove his earnestness to educate himself.

The wealth of the world is a universal fund from which every individual has a right to acquire a share. Some acquire much more than others, but not always by ways or in a manner which commends itself most highly to those who are desirous of seeing the best influences dominating. The greater number who observe purer ethical guidance are generally insufficiently prepared to hold their place in this crush for a share of the fund.

The race is to ability and endurance, if equal conditions allow all to compete, but many, having this equal right to enter, and who could win wealth and renown, are handicapped by customs established for years.

Custom, however, should not be considered as a finality. From the beginning it has yielded to improvement and in no sphere of our environment should it more easily be forced to yield, than when the nation's source of progress is clogged, and the necessary freedom in opportunity is supplied, for producers to equal, if not to surpass, their competitors of other lands.



J. P. Murray

At present Canada is proud of her Conservation Commission looking to the care of our national resources. Have we a greater or more valuable resource than our boys, and, are they not worth spending money on?

It may then be permitted to submit for consideration a suggestion, which if tried, would open up new ideas, give to the country-boy a wider sphere for his ambition; give the University, through the advanced student or post graduate, an opportunity of getting into close touch with actual practical machinerp and materials, doing commercial work. It would let the advanced workman in the workshop rub shoulders with the student workman, who hopes to be a more advanced workman. It would give entertainment in towns and other places where amusements are lacking. Entertainment is restful and entertainments may be instructive. It is not difficult to surmise that from the experience gained, present University theories having been applied to practical work will be found to require considerable modifications and by the necessarily inductive reasoning by the graduate, and the University, better methods would suggest themselves and very much better results obtained.

The suggestion above referred to, is for a system to be planned by which advanced students, graduates or post graduates may be organized into an institution which will supply scientific lecturers to small towns who are not able to undertake the heavy charge of technical education.

These traveling lecturers would be sent throughout the province, during recess time, from May until October, and would be better for the workshop employes than the most complete correspondence system. For the student or graduate, the association with practical work would induce investigation and deeper research and this would develop practical results from abstract thinking.

The question may properly be now asked how is this to be made feasible? In answer, it may be said, that but four things are required, three of which are now available. They are: the traveling lecturer, the buildings in which to lecture, the practical industry, and the one to be supplied, the expenses.

The first we have in the number of University students who probably would be glad to avail themselves of such an opportunity to improve by teaching and practice, advance their position and also acquire a considerable amount of valuable information for themselves and the University. They would be able to do this at no cost to themselves but would be quite a little ahead when their season was over.

The second, the buildings in which to lecture, are already built and in waiting. The schoolhouse of every hamlet, village or town stands closed from early in the afternoon until class hour next morning; closed when it might be profitably used by workmen of the local industries; where the traveling library may be housed during its time in that district; and where the traveling lecturer may gather around him in the evening the boys and workmen. The following day, while the school is being used for its original purpose, the traveling lecturer would be in the factory or mill, aiding where his knowledge is available and on his part, learning from the actual doing and testing the empirical effort of the college laboratory.

The next item—the practical industry.

No need to point them out as every place which has a schoolhouse has a local industry or two.

The last is necessary to the success of the whole.

This sum required would be so small in comparison with the benefits to be derived, that it could hardly be imagined that a government with the desire to advance technical education would hold its consent. Estimate, say, fifty students, for six months, covering traveling expenses and an honorarium. There should be little hesitation in finding the very small sum which such a very great desideratum would cost.

The technical education of the country-boy, the improvement of the country-workman and the better qualifying of the graduate are not the only benefits to be derived from this suggestion if made operative.

One of the grave problems of the day is, to keep the youth of the country, in the country, near the land and not let him drift into the city. And properly so. City life has many alurements for inexperienced youth and too often it has been the undoing and ruin of many who would have developed into men of great mark had they not been taken in their tender years from their country home.

The boy coming to the city for his education may be said to be lost forever to his home. But can he be blamed for having an ambition to do better than country life offers to-day? He has no chance to select a vocation nor to discern his ability. So, at considerable cost, both of heart and money, he leaves his childhood home to try to win in the throng and bustle of city life, that will-o-the-wisp, "success," away from parent and pastor, both of whom would keep him good but——.

The one great lever which can raise all workmen to the same platform, giving to each an equal opportunity, is education. It will lift the workman's possibilities and aided by an unrestricted freedom for the honest effort of properly trained ability, will make him the co-equal of any. And, as the children of the State are all equally subject to acknowledged authority, so should this governing authority recognize this right for an equal treatment of the children.

The foregoing thoughts are but one phase of a subject which gives many, sides, any one of which might well deserve a very careful study by our universities. The present method of education, and the freedom of franchise, suggest the supplying of children's clothes for the adult and stuffing the child with man's food.

Mr. P. W. Ellis saw the future of Canada. He referred to the great part the university was playing in the country's development. He made special reference to the scientific uses of the waters of Niagara Falls and the water powers of Ontario in the development of electricity as a substitute for coal.

"The Engineering Profession" was presented by R. H. Johnson and responded to briefly by W. J. Blair, a graduate of the School, now Mayor of New Liskeard, and Dean Galbraith.

During the evening special selections were rendered by the Science Octette, consisting of J. G. McKinnon, H. Stuart, J. L. G. Stewart, C. B. Ferris, W. C. Blackwood, A. A. Kinghorn, J. H. Craig, R. B. Chandler; Mr. C. Bush was conductor.

The entire executive deserve the greatest credit for the able management which brought the dinner to such a successful issue; also Prof. Wright, whose assistance in all such events is almost invaluable.

THE BEGINNING OF ELECTROCHEMISTRY.*

SAUL DUSHMAN, M.A.

The last quarter of the eighteenth century saw an immense transformation in chemical science. Lavoisier, the great French chemist, had by a series of masterly investigations established the Law of Conservation of Mass as a fundamental principle of the science. "Nothing is created, either in the operations of art, or in those of nature; and one may lay down the principle that in every operation there is an equal quantity of matter before and after the process, that the quality and the quantity of the principles are the same, and that there is nothing but certain changes, certain modifications." These are Lavoisier's words. In the face of rapidly accumulating facts, the old phlogiston theory with its constantly varying conceptions had to recede and finally vanish, while in its place arose the new chemistry based on the study of the **quantitative** relations between the substances taking part in chemical reactions. It was recognized that certain substances are definite, distinct and homogeneous, and the object of chemistry was declared to be the investigation of the ultimate components which constitute the different substances found in nature.

Chemistry was thus in a position to interpret the new scientific discoveries which were made about the end of the eighteenth and beginning of the nineteenth centuries, discoveries were not only to profoundly affect the history of chemistry itself, but to lead to the development of a new branch of science, that of dynamic electricity.

From the sixth century before the present era, when it was accidentally discovered that rubbing amber causes it to attract light bodies, to the year 1789, electricity had not made any great progress. During the eighteenth century there had been a gradual evolution in machines for the production of so-called static electricity, and physicists in general attempted to rival each other in the size of machine they could build or the length of spark that these machines could produce. Theories and hypotheses were, of course, not lacking. Some crude instruments for quantitative investigations had been devised and the main facts known at that time could be summed up in a few generalizations, the most important of these being Coulomb's laws governing the attraction and repulsion between two electrically charged bodies.

---

*In connection with the preparation of this brief sketch, I have made free use of Ostwald's Geschichte der Elektrochemie as well as of Pattison Muir's History of Chemical Theories and Laws.

Galvanism.

During the last decade, however, of the eighteenth century certain discoveries were made which gave a new trend to the study of both electricity and chemistry. In 1791, A. Galvani, a physician of Bologne, published a small volume containing a description of certain new phenomena which had been observed by him. He writes as follows:

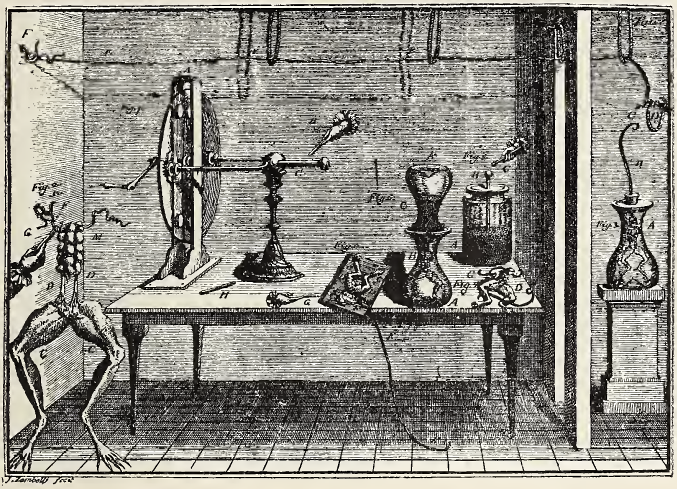


Fig. 1

"The matter began in this way: I dissected a frog and prepared it in the manner shown in Fig. 1 (left-hand side of diagram); then, while intent on some other matter, I laid it down on a table on which stood an electrical machine. . . . Now as one of the assistants happened to touch the nerves, DD, with his scalpel, all the muscles appeared to contract as if afflicted with heavy cramps. The other assistant believed, however, that the contractions occurred at the same time as sparks were drawn from the machine. Astounded at this new phenomenon, he drew my attention to it, for I was engaged quite otherwise and was engrossed in meditation. Thereupon I became possessed of an incredible eagerness and desire to inquire into this phenomenon and to bring to light whatever might be hidden therein. I, myself, therefore touched one or other of the nerves with the tip of the knife, and, at the same time one of the assistants drew sparks from the machine. The phenomenon appeared again as before."

After describing a number of other experiments, Galvani goes to to state that contractions were also obtained without the use of the electrical machine, by touching with a metallic connector the muscles of the leg and the copper hook on which the specimen was suspended. (This is illustrated in Fig. 2.) With a connector consisting of some non-conducting material the contractions did not appear. The same muscular motions were observed when the specimen was laid down on a metal plate. But the peculiar circumstances noted in all these experiments was that the contractions were much more violent when the connection between nerve and muscles was made by means of two different metals. "Thus, when the connector, the hook and the metal plate are all of iron, it often happens that the motions cease completely or become extremely weak. If, however, one of the above articles is of copper or silver, the contractions are much greater and last longer."

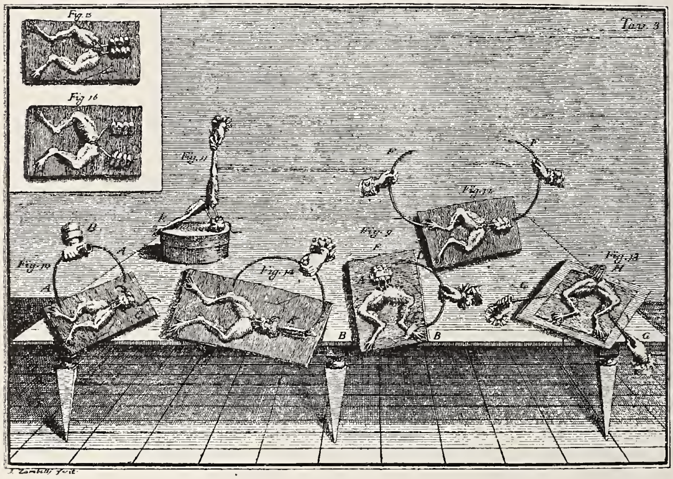


Fig. 2

How explain these phenomena? "From what has been investigated and is known, I believe that it is evident that animals possess a peculiar electricity of their own. . . It is distributed throughout all the organs and parts of every animal, but is best exhibited by nerves and muscles. The peculiar and previously unknown property of this kind of electricity is that it passes from muscles to nerves, or rather from the latter to the former." That is, the nerve and muscle bear the same relation to each other as the coatings of a charged Leyden jar; by connecting the nerve and muscle through a metallic conductor, a discharge occurs just as in the case of the latter. Of course, the implicit assumption in this explanation was that the electric charges are already present in the animal. Such an assumption, as has been pointed out by Ostwald, was quite natural; but wherein Galvani made the mistake was in not stating that it was an hypothesis, which therefore ought to be confirmed or disproved by separate experiments.

Volta's Investigations.

It is therefore not surprising that another explanation soon appeared which transferred the phenomenon of Galvanism from the realm of physiology to that of physics. Volta, a distinguished Italian physicist, directed his attention to the fact which had been neglected by Galvani; namely, that the contractions were much more violent when two different metals were used as "discharge conductors." From this he was gradually led to the conclusion that in Galvani's experiments the frog's legs play a double function: one, as a sensitive electroscope or electrometer* and the other, as an actual-generator of electricity. The manner in which Volta arrived at this conception is evident from the communications which he addressed at various times between 1792 and 1796 to different scientific journals. In a "preliminary communication" of 1792, he describes how electrical phenomena may be exhibited by interposing a moist conductor between two different metals. In a later communication, we find the first mention of the voltage series. After

Fig. 3. A. Volta

---

*The electroscope or electrometer, as devised by Bennett, 1786, consists of two gold leaves suspended in a glass case. The leaves are connected to a metal cap on top of the case; by bringing any charged body in contact with this cap the gold leaves are made to diverge.

again asserting that the motions of the frog's legs are due to the production of electricity by the contact of two different metals, he mentions that by placing one metal in contact with the tip of the tongue, and the other metal in contact with its lower edge, a peculiar sensation of taste or light is produced when the free ends of the metals are made to touch; "and these sensations and motions are stronger, **the further apart the metals are** in the following series: zinc, tin-foil, ordinary tin, lead, iron, brass and bronzes, copper, platinum, gold, silver, mercury, and graphite." Later on he gives a more systematic statement of his theory. "The contact of different metals (conductors of the first-class) with other liquid conductors (those of the second class) excites and disturbs the electrical fluid and gives it a certain impulse. Do not ask me the reason for this; it is enough that it is fact, and a general one at that. This impulse, whether it be one of attraction, repulsion, or some other kind, is different and unequal for various metals and liquids. . . You now see wherein the whole secret, the whole magic of galvanism consists. It is no more than an artificial electricity set in motion by the contact of **heterogeneous** conductors. It is these different conductors that are the real source of the electricity, and this law holds not only for metals or conductors of the first class, as one might have believed, but also more or less for all conductors, according as they are more or less different in nature. . . As long as you proceed from these laws you will be enabled to explain all the observations made hitherto, without having to trust to any assumption as to the existence of an active animal electricity. If, however, you abandon these fundamental laws, you will meet in this extensive realm of experiments with nothing else but uncertainties, anomalies, and contradictions without end, and everything will become for you an insolvable riddle." Comment is hardly necessary!

In answer to the question as to whether the electricity had its origin at the contact of the two metals or at the contact between metal and liquid, Volta referred to his experiments with the electroscope. As he had observed that the mere contact of two different metals was sufficient to produce an electric charge on each, he concluded that the electricity was always produced at the contact of the metals. "Herein, as we shall see, lay one of the most fruitful mistakes in electrochemistry."

A most important advance was made by Volta in the invention of his battery. A description of this is contained in a letter to Sir Joseph Banks, president of the Royal Society of England. As shown in Fig. 4, it consisted of pieces of silver and zinc arranged alternately and separated by layers of moistened cloth or leather. The apparatus was found capable of producing shocks comparable in magnitude with those of a Leyden jar. What was still more wonderful, it gave a **continuous** discharge, "without the aid of any external means of renewing the electric charges!" It was observed that the electrical effects of the battery increased with the number of pairs of plates in series, and Volta gives an experiment illustrating this. A battery was made by arranging in order sixty beakers, each containing a zinc and silver plate in salt solution. In the first twenty, the silver plate of one beaker was connected in series with the zinc of the next, in the second twenty the order of the plates was reversed, while in the remainder the plates were arranged in the same order as in the first set. "Now dip one finger in the water of the first beaker and then, by means of a plate held in the other hand, touch in succession the connectors between the different beakers. . . You will begin to feel a slight stimulus in the fingers when you have reached the fourth or fifth beaker, and as you pass on to the sixth, seventh, and so forth, the shocks will become greater until you reach the twentieth; then as you pass on to the twenty-first, twenty-second, and twenty-third, the shocks diminish in intensity and gradually become weaker until at the thirty-sixth they are scarcely perceptible and are completely absent at the fortieth. When you have passed this . . . there will be no noticeable stimulus until you reach the forty-fourth or forty-fifth; from then on the shocks continue to increase until the end of the series, when they are as intense as those obtained with the first twenty." The noteworthy feature in this is the demonstration that by means of an arrangement such as the above it is possible to obtain a **graded summation** of the electrical effect or tension produced by one pair of plates and a liquid conductor, and that these tensions may be added or subtracted by arranging the plates in different ways.

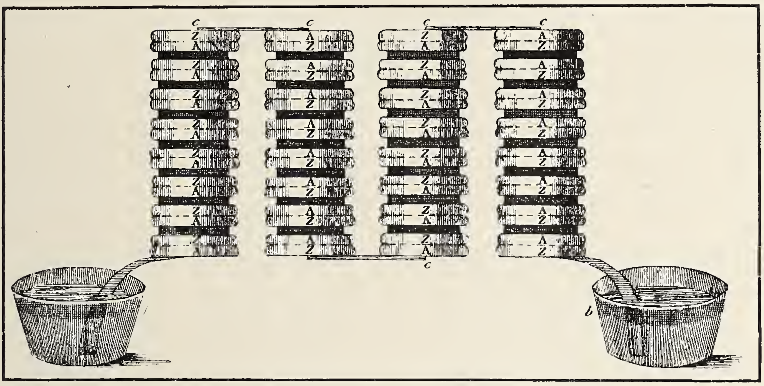


Fig. 4

Decomposition of Water.

Undoubtedly Volta must have noticed some chemical changes in the zinc plates, and in some of his experiments there must have been an intense evolution of gas due to the decomposition of the water. Yet he makes no mention of any such observations. As Ostwald states, he had his theory of contact electricity already evolved before the fact was brought to his attention that chemical reactions in the cell are the necessary accompaniment of the electric current produced by it. Volta actually believed that his battery was a perpetual motion machine, and refused to recognize that the relation between chemical action in the cell and the galvanic current is the same as that between cause and effect. For a long time this oversight on the part of Volta greatly hindered the advance of electrochemistry, and even at the present time, the ideas taught by his school have not been completely eradicated.

As soon as the communication from Volta reached London, and even before it was published, knowledge of its contents spread amongst the physicists there. Two of these, Nicholson and Carlisle, immediately set about repeating Volta's experiments, and it is a curious fact that one of the first discoveries made by them was the chemical action of the galvanic current. On connecting the end plates of the battery to two brass wires under water they observed that the wire connected to the silver plate was oxidized, while hydrogen gas was evolved at the other. At platinum wires, oxygen and hydrogen gases were formed in about the proportion of one to two volumes, and the conclusion was therefore drawn that the water was decomposed by the cement into its constituents. Nicholson and Carlisle also noticed that acids were produced at the same wire as oxygen, and alkalies at the other wire.

Before proceeding with an account of the many investigations so brilliantly initiated by the work of these two experimenters, it is necessary to remark that although they were the first to decompose water by the galvanic current and to obtain oxygen and hydrogen separately, yet the existence of a relation between electricity and chemical reactions was by no means a new observation. In the middle of the eighteenth century Beccaria succeeded in reducing various metallic oxides by subjecting them to the action of an electrical machine. Priestley noted that an acid is formed by passing spark discharges through air over water and assumed the compound to be carbonic acid, but Cavendish recognized it as nitric acid. Van Marum repeated Priestley's and Beccaria's experiments and observed that the electric spark produced not only reduction of oxides but also, under other conditions, oxidation of metals. Finally, in 1789, Deimann and Paets van Troostwyk decomposed water by means of the electric discharge.

Immediately after the publication by Nicholson and Carlisle of their results, and in the same year, Cruikshank succeeded in decomposing various metallic salts such as copper sulphate and silver nitrate and observed that the metals were liberated at the same wire as hydrogen (in the decomposition of water).

The interest aroused by these discoveries was very great. Everybody who could afford a few silver coins now made a Voltaic battery and tried experiments on the decomposition of all kinds of substances; in consequence the scientific journals were filled with records of many so-called discoveries, most of these, naturally, being more or less imaginary.

One of the very few who investigated these phenomena with real scientific acumen, was Sir Humphry Davy, the director of the Pneumatic Institute. From the first he was led to favor the "chemical theory" of the Voltaic cell as contrasted with the "contact theory" of Volta and his adherents. In this he was influenced by the observation that the power of the battery to decompose water and to produce shocks increased in the same proportion as the rate at which the zinc was oxidized. But it was mainly through two investigations, published between 1806 and 1807, that Davy attained an international reputation. The first of these dealt with the anomalous production of acids and alkalies in the decomposition of "pure" water. Davy showed that this phenomenon was due to impurities produced by the solvent action of the water on the containing vessels, and that when care was taken to obtain absolutely pure water there were formed no other products but oxygen and hydrogen. The second investigation resulted in the preparation of the metals potassium and sodium from their fused hydrates (which had previously been thought to be elements) by the agency of the electric current. In 1808 the metals of the alkaline earths were similarly obtained.

Fig. 5. Sir Humphry Davy

Not content with merely giving an account of his results, Davy also formulated an hypothesis by which he attempted to connect positive and negative electricity with the chemical reactions between different substances. His suggestions were later adopted by Berzelius in his famous electrochemical theory. It would be going beyond the scope of the present article to discuss, even briefly, Berzelius' views which were, after all, of much greater importance to purely chemical speculation than to electrochemistry. The electrochemical investigations carried out by Berzelius and Hisinger (1806) were of fundamental importance for the development of this theory. Since in the decomposition, by the galvanic current, of the salts of the alkalies and alkaline earths (the only compounds investigated by them) acids and alkalies are produced, Berzelius concluded that all salts are decomposed by the current into acids and alkalies. Thus potassium sulphate (K_2SO_4) was assumed to decompose into K_2O and SO_3. In the case of chlorides he believed at first that chlorine is an oxide of some unknown element and was convinced of his error only after a great many years. Probably if he had begun his researches with the metallic salts his views on chemistry would have been radically different; but as it was, his speculations influenced chemical theory for a long time and thus partly offset the services rendered to the science by his many important discoveries.

Physical Conceptions.

While the invention of the Voltaic battery thus led to the development of a new and extensive application of the galvanic current to chemical reactions, the more purely physical conceptions of potential, current-strength, conductance, and resistance also became gradually defined, and since these terms and the ideas involved in them are of extremely great importance in the history of electrochemistry a few remarks on this subject will not be out of place.

The first experiments with electrical machines led physicists to perceive that various charged bodies produced shocks of greater or less effect when brought into contact with the human body. This was expressed by saying that the electricity present in that body which produced the most painful effect possessed a much greater **intensity.** The next advance was made by means of the electroscope; it was noticed that the more intense the physiological effect, the greater the degree of divergence of the gold leaves, and since a physiological effect is more or less a question of personal temperament, it became customary to define intensity by the degree of divergence observed in the electroscope leaves.

It is worth noting that in the conception of **temperature** there was a similar development. At first, bodies were classified as hot, cold and so forth; but when it was perceived that a column of mercury in a glass tube increased in volume as the degree of hotness of the body with which it was placed in contact, the change in volume of the mercury was defined to be a measure of the temperature, or degree of hotness.

About 1782 Volta expressed himself as follows; "By **intensity** I understand the **tendency** with which the electricity strives to escape from all parts of an electrified body; to which tendency correspond the electrical phenomena of attraction, repulsion, and especially the degree of divergence of an electroscope." The same idea was applied to the Voltaic cell; the electric charge on the zinc possesses a different intensity to that on the silver; on interposing a conducting medium a discharge occurs from one to the other. We have previously given an account of Volta's experiment with the battery of sixty cells; from this he concluded that the **differences in intensity** between zinc and silver may be added or subtracted; that is, they possess not only a **definite magnitude** for each pair of plates, but also a **fixed polarity.**

Volta's Potential Series.

Volta now began an investigation in which differences in intensity of various galvanic combinations were measured by means of a modified form of electroscope. The divergence in the gold leaves produced by a zinc and silver plate was **measured.** "Other metals when brought into contact produce a **difference in intensity** which decreases with the difference in the power of exciting electricity and is less the nearer they are to each other in the following series: silver, copper, iron, tin, lead, and zinc, in which order the electric fluid is always impelled from the preceding one to that following."*

By placing two or more zinc-silver cells in series the divergence of the leaves was increased proportionately. Various combinations of plates were then tried, and it was observed that the **difference in intensity between any two metals in the above series is equal to the sum of the differences between those intermediate.** As Volta says: Assume that silver impels the electric fluid to copper with a force 1, copper to iron with force 2, iron to tin with force 3, tin to lead with force 1, and lead to zinc with force 5, then the difference in intensity (or **potential,** as we designate it at present) between silver and zinc is equal to 12.

It was subsequently shown by Pfaff (1808) that the above order of the metals varies with the nature of the intermediate liquid. The difference in intensity of the plates in a galvanic cell thus came to be considered as a distinct property of depending upon the nature of the metals used and the solution, but **independent** of the area of the plates or size of cell. Since this difference in intensity is what causes the electricity to flow through a closed circuit, this was gradually replaced, as far as galvanic cells are concerned, by the term **electromotive force.**

---

*The tests with the electroscope showed that the zinc was positively charged with respect to the silver, hence it was concluded that the positive current flowed from the silver to the zinc (outside the cell).

Very early, however, it was recognized that the rate at which a battery produces chemical decomposition or the rate at which the zinc plates are oxidized, varies according to the substances which are connected to the terminals of the battery. Here then we have the necessity of bringing in the ideas of **conductance and resistance**; certain substances resist the flow of the electric current, so that less electricity is transferred in a given time, other substances permit a large amount of electricity to pass through in the same time. The notion that rate of chemical decomposition and rate of flow of electricity are proportional was also vaguely present in men's minds. It remained, however, for Faraday to demonstrate conclusively that such a relation exists.

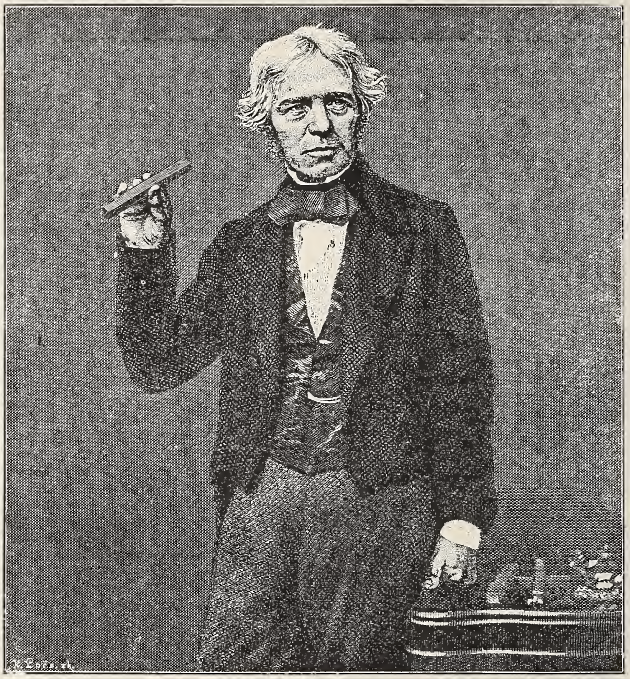


Fig. 6. Michael Faraday

In 1820, Oersted discovered the action of the electric current on a magnetic needle; then followed in rapid succession the invention of the multiplicator and the compensated galvanometer of Nobili. Of very great significance for the development of electrochemistry was the deduction by Ohm, of his well-known law (1826) connecting potential difference, current strength, and resistance. Through the masterly investigations of Fechner this led to a much more accurate definition of electrical units.

With the evolution of these quantitative methods of investigation, electrochemistry was established on a firm foundation; but it took many years before the struggle between the chemical and contact theories came to an end in the complete overthrow of the latter. The story of this long and useless debate extending over half a century is neither interesting nor profitable, so that here our sketch of the beginning of electrochemistry must close. To attempt to recount the developments in this subject since the time of Faraday would be equivalent to undertaking to write a treatise on electrochemistry, an intention which the writer does not possess.

NOTES ON PIPING SYSTEMS FOR STEAM POWER PLANTS.

A. G. CHRISTIE, '01
Steam Engineering Department, University of Wisconsin

As soon as the size and number of the engines have been decided upon, the next step in the design of a steam power plant should be to lay out diagrams of the complete piping system. From these diagrams not only can the relative location of the different machines be settled, but the form and character of the building itself will also be settled to a certain extent.

The piping system selected must provide for repairs while the plant is in operation. If the plant is to run continuously, the system must be so arranged that sections can be cut out for repairs. If, however, the plant only runs for a few hours a day or if only for a very short period, flexibility of the piping system is not essential.

Few designing engineers seem to realize the necessity of complete and well thought out diagrams of every pipe system in the station. The erection cost of the plant will be greatly reduced where the designs cover every detail even to drip lines, especially where the piping is installed under contract. Delays in getting under way and the annoyance and trouble of finishing up details by the operating force, are avoided where the piping is installed complete. The writer recalls one plant where the small details were overlooked and which were installed by the local force. The cost of material and labor to finish these parts amounted to nearly half of the contract price of the main systems.

Poorly designed pipe lines which are always giving trouble have a demoralizing effect on the operating force. These men as a rule take a deep interest in their plant if it can be kept in good shape, but soon get disheartened and discouraged when they have to stay after hours and work under difficulties over a hot boiler repairing some leaky steam line only to find the next day that there is trouble with some other portion. Many of these difficulties would be overcome and many mistakes avoided by careful consideration of piping diagrams before the plant is designed.

The first point to be decided is the selection of the system for the main steam piping. This in many instances consists of a long pipe into one end of which the boilers deliver steam while the engines are connected to the other end. This system is probably the worst that could be selected, for should any trouble occur on this pipe, there is no chance to repair it, for as a rule no valves are provided to divide the line into sections. Fortunately, however, few modern plants are designed with this system.

A few years ago, loop systems were used to some extent. However, these necessitate considerable first cost and the condensation losses have been found to be very high. The system, while providing for every contingency on paper, is apt to have too many valves and in the excitement during some trouble the operator is sure to open or shut the wrong valve.

Another system similar to the previous one is the duplicate main. This system is very costly to install, has high radiation losses, has a great number of valves, usually involves considerable repair work to keep joints tight and if one line is dead, it is subject to expansion and contraction troubles. As a whole it is not as satisfactory a system as the loop system.

In large plants, the unit system is principally used. This consists of an engine piped direct to its own set of boilers. The piping is thus very simple as each engine and boiler form an elementary power plant by itself. Sometimes each unit has its own set of auxiliaries, although in general, the complete station auxiliaries are grouped and form a system by themselves. The steam lines of the various units of the plant are connected to each other by cross connections so that one unit can help out another in emergencies.

For smaller plants this system may be modified by placing the boilers and engines back to back with a division wall between. The main steam line which is usually on the boiler room side, is divided by valves into sections so that each section connects with one or more boilers and supplies one or possibly two engines. By working over the diagram it will usually be found possible to cut out one section for repairs and still be able to operate the greater portion of the plant. This reduction of plant capacity is one of the chief objections to this system. Its chief advantage lies in reduced first cost, its simplicity and the small number of joints, and hence small repair bills if well put up. The last system is now used very extensively and in general gives good satisfaction when the piping and valves are of good material and well put up. Freedom from complexity should be aimed at in every case for it seems to be almost always the case that trouble occurs at such a time that the cool-headed engineer is not on the spot. Then the simpler the system, the less chance for the excited fireman to open or close the wrong valve.

Probably the final selection of a system will be made on the basis of cost. But it is well to remember that the safety of life and property are dependent on good reliable pipes and fittings and for this reason alone besides that of reliability of operation, repair bills, etc., it is always desirable to install high-grade piping systems.

Next comes the selection of a system of steam piping for auxiliaries. In plants of small capacity the auxiliaries take steam from the main line. In large plants they are usually provided with a system of their own. The auxiliaries, which are usually, comparatively speaking, cheap machines, do not operate satisfactorily on superheated steam and consequently are usually supplied with saturated steam from the boiler drums by a pipe system of their own. In some states such a system is insisted on by the boiler inspectors and underwriters so that failure of the main steam line, or a shut down for repairs, does not cut steam off the boiler feed pumps, the fire pump and the exciter. The safety of the boilers in case of trouble is largely dependent on the boiler feed pump in order to prevent low water troubles. The fire pump must always have steam. The power plant itself should be lighted by the exciters and under no circumstances should it be allowed to be in darkness. In case forced or induced draft is used, the engines driving the fans should be included with the above unit.

These auxiliaries should be in duplicate and so located, and the auxiliary steam line so designed that continuity of operation is assured. It is advisable to have these near the centre of the boiler plant so that the auxiliary main can be divided into sections.

The feed water piping is usually installed with a system of duplicate mains, with separate connections to pumps and boilers. As a rule these are the only pipe systems to which much attention is given in the boiler room. But the systems for auxiliary exhaust steam, for heaters and economizers, for blow-off pipes, for drains and sewers, for drips from main steam lines, from auxiliary lines and from the boilers themselves, should be gone over individually and a system selected. No general statements can be made regarding these for, as a rule, they are largely dependent on local conditions of the plant being designed. However, in the design of the station each of these systems should be worked out carefully.

After the whole plant has been worked over diagramatically, then the machinery can be located, floor and building plans drawn and piping drawings can also be made. The piping drawings will show the sizes of pipes and the location of pipe lines relative to the building, to boilers and to other fixed machines. All the pipe systems should be drawn out so that there may be no interference of different pipe lines. Alterations of the original systems may have to be made so that the pipe lines may be accessible for operation aand repairs. The location of valves and traps should receive most careful consideration for very often these are located in places, which if not inaccessible in a hurry, at least are not easily got at and hence are often neglected and allowed to get out of order. Galleries should be provided along the main steam header for use in operation and repairs. The most suitable radius of each bend should be determined and placed on the drawings.

Almost all large piping jobs are done by contract, by one of the large pipe concerns. If it is intended to let such a contract for the plant being designed, it is not advisable to detail the piping as the contractor has designers who can do this to the best advantage as they know the standard sizes of their fittings and their methods of cutting and assembling pipe.

After the location drawings are made, as just outlined, the specifications for the piping, fittings, valves, separators, traps, pipe coverings, etc., can be prepared and the pipe contractor required to submit detailed drawings with his bids. If, however, the piping is to be done by some local concern or by pipe fitters employed by the company for whom the designs are made, then detail drawings of the complete plant should be prepared.

One point which must be kept in mind in laying out all piping, is to allow for expansion. The writer recalls a plant with 30 feet of horizontal exhaust piping and no allowance for expansion at either end. Considerable money was spent to change the footings under the condenser so that it could move on rollers. An expansion joint was out of question on account of the size and cost. It is often advisable with steam mains to have the pipe cut so that when anchored in the middle the ends will be in correct position only after expansion under operating conditions. In erecting, the pipe connections to engines and boilers may have to be sprung into place but will correct themselves when heated up.

In considering the details of the different systems, those connected with the main steam pipe should receive close attention. The main steam pipes may be either of wrought iron or steel. The latter is now generally used and for best service should be standard weight lap-welded Openhearth steel up to 125 lbs. dry steam if threaded, and up to 200 lbs. when welded flanges or "Van Stone" joints are used. Above these pressures use extra heavy pipe. When superheat is used, it is advisable to avoid all threaded joints as they are subject to leakage troubles.

Formerly all flanges were of cast iron. Practice now seems to favor steel flanges in every case above 3 inches as they are less liable to break in tightening up over gaskets. Where ground joints are used, no gasket is necessary and the joints are simply painted with raw linseed oil while being assembled. With other classes of joints gaskets are required. The flanges may be turned flush or may be made male and female. The latter have one advantage in that the gasket is not liable to blow out, but this form of joint is very hard to repair.

For gasket material, rubber and vulcanite compositions are suitable for wet steam up to 100 lbs. For higher pressures and for superheated steam wire-woven asbestos, corrugated copper, soft sweedish iron, smooth-on, and other metallic gaskets may be used. When high superheat is used, great care must be taken when laying out steam lines, to see that repairs to gaskets can be readily made for repairs will be surely needed. Copper gaskets should not be used with superheat as they usually fail due to pitting. The life of a gasket will largely depend on the care exercised in fitting up the joint. It should be drawn up evenly all around and not strained and flattened on one side. The life also depends on the proper drainage of the steam line, for condensation lying to some depth on one side of a pipe invariably starts a leak in the gaskets.

Gate valves are used for dividing the main into sections and for steam connections from the boilers and to the engines. These having outside nickel steel stems are preferable as they give an indication of the position of the valve inside. The bobies may be of well selected iron with heavy ribbed walls so as to avoid distortion of the valve faces. Since cast iron is not considered by many engineers as suitable for superheat, valves are being made of semi-steel and even of cast steel. These give excellent service but are expensive. The discs and seats of these valves should be of high-grade cast iron or of nickel steel. The use of brass or bronze seats should be avoided with superheat as electrolytic actions are frequently set up with the iron in the bodies. Globe valves are seldom used except as engine throttles The valves on the boiler connections should be located at the highest point so as to avoid pockets to collect condensation. One of these valves should be an automatic non-return valve.

It is not intended to discuss the sizes of pipe for mains, etc. Since velocity losses are reduced by superheating, smaller sized pipes can be used and thus radiation losses are reduced. The pipe size may also be reduced when steam turbines, taking a steady supply of steam, are connected to the line. In fact, the real criterion for pipe size, is to make the sum of velocity losses and radiation losses a minimum.

Fittings are usually made of cast iron. More recent installations have used cast steel fittings and in some cases have done away wth fittings altogether and have welded flanged nozzles for branches on to the pipe itself. This is a decided advantage for less joints are used and hence less places to repair. The pipe line is also of homogeneous material.

When fittings are used, care should be taken to avoid the formation of pockets as the collection of water in these is a source of trouble. Those fittings should have long fillets whose branches or flanges are cast on so as to minimize casting strains.

Wherever possible it is advisable to use bends of long radius in place of elbows. The number of joints is reduced, the drop in pressure is also reduced and expansion takes care of tself.

Provision should be made to anchor the main steam pipe at one point, preferably the middle in pipes of moderate length. Saddles through which the pipe can expand should be provided at intervals. If the pipe is long U bends may have to be provided in the central portion. Sliding expansion joints should never be used when bends can be installed.

All steam lines should be amply provided with drains leading to traps. The piping for these should be carefully laid out and also the piping for the disposal of the trap discharges should be shown. If the plant is large enough to warrant the expense the discharges may be led to a receiver from which a small pump forces it into the boilers. Otherwise the trap discharges should be piped to the heaters where the hot condensed steam has a decided value.

In piping up drips, drain lines and other small piping it has been found that a cheaper and more satisfactory job is obtained by using bent pipe with couplings in place of regular fittings whenever this is feasible. Pipe fitters soon learn to do rapid and neat bending and soon prefer it to fittings. The finished job presents a neater appearance and by the elimination of joints, it lasts longer and requires less repairs.

All piping carrying live steam should be well covered with a suitable heat insulating material, as the radiation loss is a fixed quantity depending on the temperature of the steam aand efficiency of the pipe covering. The very best covering for the conditions, should be purchased. Also all fittings, flanges, valves, drip lines, traps, etc., should be amply covered and the saving will pay high interest on the cost of covering.

Connections to engines should be taken off the top of the header to provide as dry steam as possible. A valve should be provided at this point so that repairs can be made on this piping. Here again long radius bends should be used in preference to elbows. A separator or receiver is usually placed before the throttle valve to insure dry steam and in reciprocating engines to provide a large supply of steam close to the engine and thus reduce the drop in admission pressure in the engine. Auxiliary steam lines in general have practically the same equipment as the main steam lines. The main point to watch in the design is to provide connections so that in any emergency, it is still possible to keep the boiler feed pumps going.

Exhaust lines are usually of cast iron or riveted steel. When high vacuum is desired tight exhaust lines are absolutely essential. Air leakage of cast iron piping is rather an indefinite quantity and requires some investigation. The chief sources of leakage are chaplets for holding cores, porous castings and blowholes, and joints. The gaskets should all be tightened up after the pipe is hot and the pipe lines should be painted under vacuum with heavy asphatum paint.

The location of exhaust pipes is largely determined by the local conditions. The connections to the condenser should be as short and direct as possible. All valves should be heavy gate valves. An atmospheric exhaust pipe and automatic relief valve must also be provided.

Proper allowance must also be made for the expansion of this pipe either by providing large copper expansion joints or by placing the condenser on rollers.

The boiler feed piping should always be in duplicate so that a failure of one pipe does not endanger the boiler. The spare feed line when not used for boiler feeding purposes can be supplied with city water or water from a service pump to run boiler tube cleaners, to wet down ashes, to wash floors, for toilet purposes, for water-cooled bearings, etc.

The feed pipes should also be provided with bends in place of elbows to reduce vibration in the piping. Screwed flanges can be used with rubber composition gaskets. The piping may be of brass or steel and should be made heavy as it is often called on to withstand high pressures owing to racing of the pump. The feed valves to the boilers as a rule are globe valves which permit close adjustment of the feed. The connection into the boiler should be provided with a check valve to prevent the return of the hot water from the boiler into the feed lines in case of accident.

As these pipes carry hot water, they should be very carefully covered with heat insulating material. This is especially necessary where economizers are used.

The boiler feed pumps must be in duplicate and should be fitted with a good type of pump governor. Heaters for the feed water should be provided to utilize the heat in the exhaust steam from non-condensing auxiliaries.

Another pipe line deserving close attention is the blow-off pipe. The expansion of this line at each blowing-off of the boilers must be taken into consideration and provided for. Otherwise trouble will be experienced with the blow-off connections to the boilers. This pipe should not be discharged into a sewer or other conduit as the scouring action of the hot water and steam is very distructive. It should be led into a basin into which it can discharge and from which the steam produced can escape by suitable vents. Blow-off pipes are often placed under the floor or in a trench where it is impossible to get at the joints to make repairs. This should be especially avoided. Sometimes connections and valves are provided to the boiler feed pumps and the boilers can be supplied with water from this source in emergencies.

Each blow-off connection to a boiler should be provided with a high-grade blow-off valve and with either a gate valve of a heavy plug cock. This adds security and enables the blow-off valves to be frequently inspected and kept in good repair.

Some stations are provided with oiling systems. These are determined largely by the class of engines installed, by the type of oil filters and by the local design of the station. Hence no general discussion of systems will be given.

In conclusion then for economical first cost, considering operating costs, the piping systems must be simple, flexible and accessible, the pipe lines must be of first-class material well erected, every square inch of radiating surface of high pressure steam piping and feed piping must be well covered with the best of heat insulating materials, accessibility for making repairs must be kept in mind, and all small pipe systems should receive consideration in the designs.

GAS ENGINES.*

NORMAN C. SHERMAN

Gentlemen,—It is with a good deal of trepidation that I appear before you, knowing that there are probably some men present to whom my remarks may be history and to a large number I may appear to have merely touched the surface.

However, the subject is a very comprehensive one and I can only hope to bring before you some of its outstanding features.

I have chosen to call the gas engine a development of the steam engine. In burning coal for the generation of steam there is a continual escape of heat by reason of the imperfections of the furnace, and by the discharge of heated gas up the chimney. Also there is some difficulty in forcing the heat through the shell of the boiler and conveying it to the particles of water to form steam.

It would appear then to be of manifest advantage if the heat could be applied directly to the gas without the intervention of furnace or boiler. The idea was so obvious that it could not fail to attract the attention of those who were trying to overcome the too apparent loss in the steam engine, accordingly numerous attempts were made to obtain an elastic agent by setting fire to a mixture of inflammable gas and air within the very cylinder in which the piston of an engine is working. The heat developed in the gas during the burning would thus supply a source of energy in the closest contact with the moving parts to which the energy is to be transferred. This will furnish a definition of the internal combustion engine.

Comparison may be made to a gun, the cylinder being the barrel; the piston, the bullet; the gas mixture, the powder. However in the gas engine we require instead of an explosion (1) that the pressure shall not rise too suddenly; (2) that the intensity shall be kept within reasonable limits.

About 1860-1870 several forms of gas engines were built, the Lenoir engine (1860), having a great many of the features

*Read before Mechanical and Electrical Section of Society.

of engines of the present time. This engine was not developed, however, owing to the fact that patents were granted for the Otto Atmospheric engine which operated somewhat as described by the comparison to a gun.

The piston was driven free up a long cylinder by the explosion of the gas and at the top of the cylinder the piston rod, which had a rack on one side engaged with a gear to produce rotary motion on the down-stroke under atmospheric pressure.

Following this came the Otto gas engine, this engine being the one which has so firmly established the gas engine on its present commercial basis. The new Otto engine acted on what is known commonly as the four-stroke cycle.

The cycle of operations requires four strokes of the piston or two complete revolutions. Suppose the piston at the head of the cylinder and moving forward. As it moves outward a vacuum is created in the cylinder which draws in the mixture of gas and air through the suction valve, from the mixing valve or carburetor. The suction continues till the end of the stroke when the suction valve closes on the in-stroke of the piston the gas is compressed into the space between the piston and cylinder head called the compression chamuer. This compressing of the gas renders it more explosive and at or just before the end of the stroke the gas is ignited, expansion of the gas occurs and the piston is forced outward, thus transmitting energy to the crank-shaft. When the piston is nearly at the end of its stroke a valve called the exhaust valve is opened mechanically by means of a device called a cam, and on the in-stroke of the piston the burnt gases are expelled from the cylinder head called the compression chamber. This compress- and another intake stroke occurs.

There are thus four operations (1) intake, (2) compression, (3) expansion, (4) exhaust, and since only one of these transmits energy to the crankshaft—the other three withdrawing a certain amount—the need for heavy flywheels on the gas engine is very apparent.

The ignition of the charge is accomplished by two methods chiefly:

(*a*) The hot tube system.
(*b*) Electric spark.

(*a*) A tube of metal or porcelain is inserted into the compression chamber and brought to a cherry-red by means of a Bunsen burner. This tube will ignite the compressed gas at starting and the succeeding explosions will keep the tube hot. The disadvantage this method has is that the only way of advancing or retarding the "time" of ignition is by changing the compression pressure. This system has been very largely displaced by the second method except in the case of oil engines. Two systems are employed: (1) The jump-spark, using a high tension current which will arc across a gap left between two points placed inside the cylinder—the common spark-plug being the example so well known. This system is used on automobiles and marine engines. (2) The make and break system, using an induced current of fairly low voltage but high amperage which produces an "arc" or spark between two points in the circuit when they are sharply separated. This is the system in use on large engines only instead of using batteries and coil a small dynamos or magneto is used and the "igniters" either mechanically or magnetically operated.

The heat generated by the explosion in the cylinder often reaching 2700 ° renders a cooling system necessary. For this reason the cylinders are cast with a water-jacket; that is, the walls are cast hollow, leaving a space through which water is pumped. In the last few years since double-acting engines have been built it has been found necessary to cast the piston rods and pistons hollow and cool them also by a separate water system. Attempts have been made at air-cooling by casting radiating flanges on the cylinder and having a fan revolving at a high rate of speed to furnish a current of cool air. There are some engines of this type in use but the air-cooled engine is not a very marked success and would probably fail altogether in large units.

Along the same line it has been found necessary to use only a mineral oil having a high flash test, otherwise the oil is decomposed or burned away, leaving carbon deposits on the walls of the cylinder causing pre-ignition owing to the particles becoming red-hot. In extreme cases where the oil is burned away the piston will sometimes "freeze" to the cylinder ruining either or both and perhaps wrecking the engine.

Gas engine governors are of two types:

(1) Hit and miss governor.
(2) Throttle governor.

The first is used on the smaller units. It gets its name from the fact that it automatically regulates the number of ex-explosions, each explosion being equal. The governor used by Fairbanks-Morse is a flywheel governor. When the speed of the engine increases above the limit a collar on the crankshaft is drawn outward along the shaft by the centrifugal action of the weights to which the collar is attached by two bell-crank levers. Drawing out the collar forces a ground steel lever called a "Detent" (one end of which fits in a groove in the collar, and pivoted at the centre) into a notch or a slot on the cam or lay-shaft rod, thus holding the exhaust valve open hence preventing any vacuum in the cylinder and also the indrawing of the mixture.

Thus the engine runs free and misses a number of explosions until its speed having dropped back to normal the weights swing in, withdrawing the detent from its slot and allowing the exhaust valve to close. A better method is to allow the valves to work as usual but to have the governor lift a block out of line with the suction valve so that it does not open as its appointed time.

The second type is the throttle governor. Here the governor regulates (throttles) the quantity of mixture taken into the cylinder, each explosion stroke being utilized. When the speed limit is passed the balls in drawing outward draw up a small bell-crank lever to which is attached a rod to operate the butterfly valves in the gas passages. The opening of the throttle valve thus regulates the amount of mixture. This governor has been made so sensitive that it has placed the gas engine in a position to successfully compete with the steam engine in electrical work where very close regulation is necessary to secure a steady light. This governor will give as close as two per cent. maximum variation and better.

For electrical work very heavy flywheels are used while for belt and pump drives lighter wheels suffice. The weight per h. p. of flywheel runs between 500 and 590 pounds for electrical work while in marine and automobile engines this weight will run below 25 lbs. The contrast is very great but it is well known that the latter are very short-lived even with intermittent service.

Simple Poppet valves, usually of forged steel with 45° bevelled seats are used on all gas engines of the four cycle type at least. The inlet valves are either mechanically or automatically operated. The first method is in use on all larger units. The valve is operated by a cam acting on a push-rod and rocker arm, sometimes, however, the push-rod is omitted and the cam acts directly on the rocker-arm (roller contact being provided always). The valves are nearly always mounted in cages independent of the cylinder, thus permitting of quick removal for inspection and regrinding.

Valves are in common practice made about 45-50 per cent. of the cylinder diameter. On large engines the stems are provided with rings to prevent loss of compression and to keep oil from leaking down on the working edges, causing carbonization and leaky valves.

Owing to the high pressures in the cylinder it has been the aim of several manufacturers to provide "balanced" valves. The Riverside Engine Co. have about the best example of balanced valves I could find. The valve used by them is of the poppet type only the head of the valve is left uniform in diameter for some distance up the stem. This extension runs in a liner with rings as mentioned before. Thus the only pressure which can act to hold the value on its seat is that of the helical spring and the weight of the valve. Contrary to usual practice, the valve is "pulled" open, tension springs being used. The valve gear is very simple, the lay-shaft is located on the top of the cylinders, the drive being furnished by short cross-shafts and steel gears (running in oil) from the main shaft. Cams are keyed to the lay-shaft and these cams engage with rollers on the ends of rocker-arms to raise the valves. The only force necessary to raise the valves is that required to overcome the resistance of the helical closing springs and the weight of the valves.

On engines using liquid fuels the carbureter or mixing valve consists of a small reservoir filled either by a pump or by a gravity system. The former is preferable, the overflow, if any, simply running back to the fuel tank through an overflow pipe, thus maintaining a constant level in the reservoir. The fuel is taken into the cylinder through a needle-valve along with sufficient air through the inlet valve to form a mixture suitable to conditions.

The gas-mixing valve is manually adjusted by means of valves located in the supply passages except in such cases as require variations of the mixture proportions at the same time with variation in the quantity of mixture admitted. For such conditions the lever which raises and lowers the mixture-valve is also linked to butterfly-valves in the passages, the linkage being so arranged that as the load decreases the mixture is made richer and as the load increases is made weaker and the pressure raised. The use of the butterfly-valve helps to make the governor more sensitive since it is a type of balanced valve and its ease of operation is unaffected by the pressure of the incoming gases.

On the gas engine as well as the steam engine the indicator is of the greatest use. On the gas engine, however, a very much stiffer spring must be used. In comparing steam and gas engine diagrams it will be noticed that there is very little difference in height, yet if we remember that the spring used for the steam engine was an 80-lb. spring while that for the gas engine was 160-200 lbs., we can readily see that the initial pressure in a gas engine cylinder is very much higher than that of the steam engine—also the release is at very much higher pressure. Owing to the high frictional losses in the gas engine the indicator is not as accurate as might be for measuring the horse-power but for the demonstration of the best mixture, valve setting, and "timing," of the explosion it is of the greatest use.

The use of gas engines on a large scale has been governed by the field open to this style of prime mover; that is, fields where the steam turbine and Corliss engine are not of practical utility. Two of these, the utilization of natural gas and blast furnace gas, are quite familiar to power users, but of course both are limited. Of late years, however, "producer" gas has been coming to the front. Producer gas can be generated from fuels which cannot be used economically under boilers—some of these fuels—lignite, for example, yielding only about 8,000 B.T.U.'s as fired under a boiler, but in the gas producer and engine it is possible to develop a brake horse-power on less than two pounds of the coal.

The gas producer affords practically the only means of using this coal since it is so difficult to secure proper combustion under boilers. The same thing is true of slack coal, bone coal and peat.

Underlying 20-30 million acres of public lands in the West are beds of lignite—heretofore supposed useless. The possible industrial development of the West by the producer gas plant is therefore almost unlimited. Gas producers are of two types, suction and pressure producers, the former having the widest use on this continent I will refer to it chiefly.

Producer gas is generated by passing air together with steam at atmospheric pressure through a bed of burning coal contained in a large generator or retort lined with fire-brick. The mixture of air and steam being sucked in by the action of the engine piston.

Leaving the generator the gas, which has a high temperature, is passed through the vaporizer, a cylinder filled with tubes—kept full of warmed water from the cylinder jacket—where it parts with enough of its heat to generate steam in sufficient quantities to supply the producer.

Next the gas passes through a scrubber where it is further cooled and partially cleaned from impurities which would cause trouble in the engine cylinder. The scrubber contains layers of coke over which water is sprayed, removing the dust and cooling the gas by contact with the water.

The next step is the purifier; the gas has to pass through layers of sawdust or shavings which remove the tarry products. From the purifier the gas either goes to a gas tank or direct to the engine, usually the latter.

One advantage which the pressure producer has over the suction producer is that it can use almost any kind of fuel while the suction producer is limited to anthracite, coke and charcoal.

A comparison of gas and steam plants will show that the principal differences are not in the labor, attendance and repairing costs but rather in coal and water consumption per horse-power hour in first costs and life. The gas power plant is without question of very much higher efficiency than that of steam plant and the efficiency of small gas engines is about as high as that of large ones while small steam engines make a very poor showing indeed. Hence we have a clue as to the field where the gas engine is bound to displace the steam plant to a very great extent.

The cost of operation of the gas plant is low compared to that of the steam plant but this saving is offset partly by the increased fixed charge due to the higher first cost of the gas plant made necessary by its massive, rigid construction and the necessity for more and more accurately made parts than the steam engine requires. Also the gas engine is supposed to be shorter lived than the steam engine.

In the largest units steam is so economical that gas plants of equal size suffer in comparison of power costs except of course in the neighborhood of blast furnaces or coke ovens or when coal is high in price. The gas plant also suffers when the load factor is low; that is, where the possible output is greater than the real output. This offset partly by the stand-by losses of the steam plant which tends to equalize the excess of the first cost of the gas plant.

In view of the above, in isolated gas plants it is advisable to use smaller units and when the load factor is low shut down a part of them. Thus the highest efficiency of those in use is maintained and the losses due to part load eliminated. Under such circumstances the producer gas plant can easily work at about twice the efficiency of the steam plant.

As an example, a 250 h.p. twin gas engine using coal at $2.00 per ton and at 50 per cent. load factor will develop a brake horse-power per hour on .37 cents. This cost is about equal to that of a steam plant of 50,000 h.p. of the best type and is almost absolutely unheard of in engines of a smaller size, hence it will be found that the gas plant is superior since it is capable of producing power at a total cost varying from one-half to one-fifth as much as a steam plant of equal size.

A further development of the gas engine is the gas turbine.

Experiments have been made with a small turbine of the De Laval type capable of developing about 30 h.p. and after noting its performance with compressed air, arrangements were made for using it with a combustion chamber, delivering the products of combustion of liquid hydrocarbon fuel (gasoline) at a constant pressure through a nozzle upon the blades of the turbine. The combustion chamber was lined with a refractory material and tubes were placed in the shell to provide for a water-cooling system. The temperatures reached about 3200° F. and the lining found most suitable was a carborundum shell with asbestos backing inside a metal shell. The nozzles also being of carborundum.

The water after circulating through the jacket tubes is sent through small holes into the combustion gases just before they enter the nozzles, the water being converted into steam which acts to lower the temperature of the issuing gases, preventing destruction of the blades and also by its own expansion helping to drive the turbine.

It has been found necessary that the compressed air for feeding the combustion chamber should be placed from some form of rotary air compressor so arranged that it can be direct-connected to the turbine itself.

This means that the gas turbine must include a rotary air compressor and that such a compressor must have a high efficiency otherwise it will detract very much from the efficiency of the compound machine.

In one large unit the compressor had an efficiency of 70 per cent., but it absorbed about half the power developed by the turbine. The machine running at 4,000 R.P.M. developed 300 h.p. more than that which was absorbed by the compressor.

The thermal efficiency was not as high, however, as that of the reciprocating gas engine but seeing that several 120 h.p. gas turbines have actually been installed for service in the past year and the length of time it has required to bring the reciprocating engine to its present state of perfection there seems to be a very good reason for encouragement of and interest in this form of gas engine.

THE ENGINEER AND THE FINISHED WORK.*

Technical education is a subject receiving much attention in all progressive countries to-day. Germany has set the pace. She has shown what science and skilled workmen can accomplish. Her representatives are met throughout the world, gathering scientific information regarding raw materials, regarding systems of manufacture, regarding details of workmanship, in order that these may be available in "the Fatherland" in producing an improved quality of goods at a decreased cost. This is one of the great secrets of Germany's extending commerce—technical education. England has grasped this fact, and with the foresight and business instinct, characteristic of the British people, we may confidently affirm that its usefulness will be tested to the full extent. Canada, in spite of the many demands upon our resources, is making progress in this regard, and government and educational bodies are making substantial progress in the matter of manual training and the higher technical education.

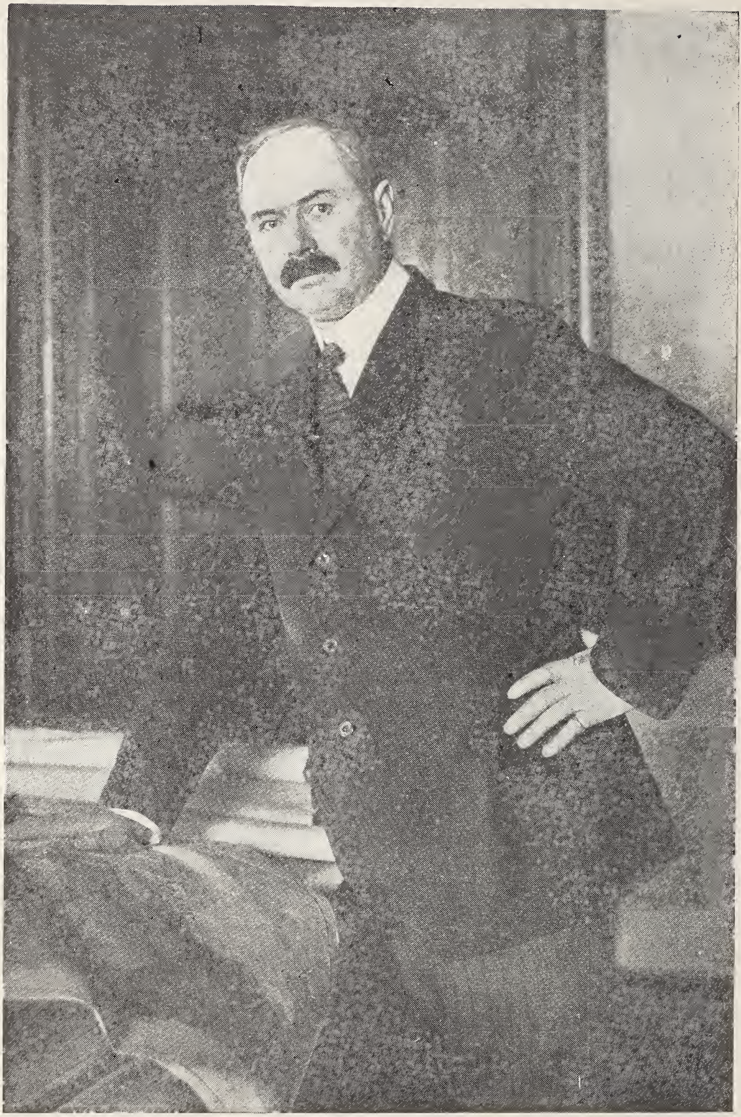
This is a subject in which the engineer is keenly interested from a direct and personal standpoint. The result of his own education of the labor, skill and care that he puts into his plans and specifications, are dependent upon the grade of workmanship available in securing ultimate results. His own skill and foresight are not sufficient, good material is not sufficient, if these are to be utilized wholly in a rough and haphazard way by untrained workmen and inferior inspectors.

The situation is one which every engineer in Canada must have at times keenly appreciated, when he has looked upon the defective work presumably carried out in conformity with his plans and specifications. Much of the engineering works carried on in Canada to-day, is intentionally designed in an inferior manner simply because of the fact that we cannot depend upon the workmanship that is to be put into them.

The designing engineer cannot himself be always on the ground to give the necessary directions which even skilled artisans require, and between the engineer and the artisan lies the office of the inspector. The training of the engineer is necessarily made up of what we may roughly term "the practical" and "the theoretical." Both are essential. With the engineer on the one hand, the theoretical should predominate. With the inspec-

---

*From an address delivered to the Toronto Engineering Alumni, on Thursday, Feb. 10, 1910.



A. W. Campbell

Deputy Minister of Railroads and Canals, formerly Deputy Minister of Public Works for Ontario tor, the practical is necessarily the most essential feature. The inspector has need of both the theoretical and the practical if he is to properly interpret the engineer's intention and at the same time apply them in such a way that the contractor can accept in full his directions.

Contractors, however honest, are chiefly concerned in the profits accruing; not the perfection and durability of the work. The contractor's foreman is chiefly concerned in getting the maximum amount of labor for the minimum wage. His efforts are, of necessity, directed toward that phase of the work. It may be accepted as an axiom that the quality of the work cannot be wholly left to the contractor.

There is a great need in Canada to-day for skilled inspectors who will act as the connecting link between the designing engineer and the contractor. The inspector is not simply a watch-dog on the work. He is there to fill a place which the contractor is not, cannot, be expected to fill. I would not separate wholly the work of the inspector from the profession of the engineer. I know of no better training for a young engineer than that experience, when, call him what you will, inspector, resident engineer, assistant-engineer, he has the opportunity of remaining on the ground and studying all the details of practical workmanship. There is need, however, that young engineers prepare themselves for the inspector's duties in a proper manner, by a period of, let us say, apprenticeship.

Theory alone will not make a good inspector. As I have pointed out, the predominating qualification of an inspector should be the practical. He should know the different grades and qualities of material. He should know the different grades and qualities of workmanship. He should know how much work a man or men do in a day, and he should know as far as possible all those details of machinery and methods of doing work which tend to good and bad results.

This information is necessary to him as inspector, but doubly essential, it seems to me, for him to have a full grasp of, when, more closely following the duties of a professional civil engineer, his work will consist of the preparation of plans and specifications, in which he will be controlled and guided by the limitations imposed upon him by the grade of workmanship, material and cost that are the tools with which he must ultimately get results. In Canada to-day we have splendid institutions of scientific education connected with our universities. We establish technical and manual training for artisans, but I would commend to you a more difficult school perhaps, but one in which the rewards are exceedingly satisfactory and gratifying, and which are absolutely essential to the highest grade of engineer. In this school he could start at the lowest rung and work his way up, as he has done in the School of practical Science. The school to which I refer is the school of Experience, in which, as with all other human endeavors, the way is hard and difficult in proportion to the goal to be attained.

Technical men are not always available, so that we are compelled frequently to employ men of more or less practical experience, but without the theoretical training. Too often we find that these are men who do not value the work of the engineer or architect. To the laymen, the architect or engineer is apt to be a man of fanciful ideas, who can write long specifications, and draw more or less intricate pictures, but who has no ideas of how the work is to be carried out. The untrained man, lacking the basic information as to why the specifications require certain results, is wholly unable to determine how it should be done, if he has not actually seen it performed in his past experience. In concrete, for instance, he has no conception of why the stone and sand should be clean, why they should be mixed in certain set proportions, why the mixing should be thorough. He blunders and stumbles along, hoping the results will be satisfactory, but can give no positive assurance that they will be.

It is the unexpected that happens. No plans or specifications can be so prepared as to meet all emergencies. When something not contemplated by the plans and specifications occurs, the layman's training is seldom equal to the occasion. His opinion of engineers and architects very frequently causes him to find a solution of his own. Lacking the knowledge as to why a thing should be done, he is incapable of determining how the emergency should be faced. When the engineer goes on the ground, it is too often to look with horror on the blunder ing work that has been carried out.

In making these statements, I am reminded that it is difficult to generalize. There are some competent laymen inspectors. But they are men who have grown up on practical work, who are shrewd observers, and have a native capacity that carries them beyond the ability of the average man. Inspectors of this class are rare, however, as they are usually employed as contractors' foremen, or graduates to the ranks of the contractor.

Towns and cities, all municipalities, are frequent offenders in the matter of inspection. Much municipal work has no inspection whatever. Inspectors, when employed, are apt to be local men with a little influence, who have been failures in their own line of work or business. They have great respect for the opinion of the contractor who is doing the work, and very little for the engineer who merely designed it. The inferior results and failures throughout the province in municipal improvements are the unfortunate verification of this situation. When failure occurs, the public look to the engineer as the responsible official, and the reputation of engineering profession has suffered much in consequence.

These are some of the difficulties which we have to face in carrying on public work. The situation is possibly one which can never be wholly overcome, but we are looking to the technical schools and colleges to supply us with men who will have the necessary practical and theoretical training, and we are at the same time educating public opinion as to the necessity of spending more upon the expert supervision of these works. The public are slow to grasp the value of expert services, and it is only with costly experience through mistakes and blunders of untrained inspectors, that these matters will ultimately adjust themselves.

I am not speaking in the interest of technically trained men but beinug a public official charged with the handling of public funds in connection with public works, I have reached these conciusions from years of experience, and deem it but right that I should give the public the benefit of this experience, and warn them in the interest of good workmanship and economy. Sentiment has been, and to a large extent, still is in opposition to skilled inspection, and where we apparently have so much difficulty in raising monev for doing these necessary works, it seems difficult to understand why we should persistently refuse to adopt the methods that will secure the most successful results.

The inspector requires technical training, combined with experience, to interpret not so much the letter, as the spirit of the plans and specifications. The inexperienced technical student is, on the one hand, apt to be too particular over unimportant details; but the lay man is careless and pliable in the hands of a determined contractor. A couple of seasons in a minor capacity, with two or three years' technical study is a training such as will enable an ambitious young man to become a thoroughly efficient inspector.

The Department of Public Works has frequent occasion to employ inspectors on works under contract. During the past season Mr. Arthur Sedgwick, a graduate of the School of Practical Science, was resident engineer or inspector in charge of regulating dams at the outlet of Dog Lake, the head waters of the Kaministiquia River. These dams were in three sections, of concrete with considerable rip-rap, and when completed it will be possible to develop 40,000 h.p. within a mile of the lake.

A work at Dryden on the Wabigoon River comprising a steel bridge of 80 feet span, concrete abutments 13½ feet high, and a filling 160 feet in length, rip-rapped, was supervised for the Department of Public Works by W. H. Manning of the School of Practical Science. Mr. J. W. Hackner, a graduate, supervised steel and concrete bridges at Nairn, Severn, Vermillion River. The Vermillion Bridge is in two steel spans of 150 feet each, with concrete sub-structure and a 300-feet timber trestle. The Nairn Bridge is of steel 200 feet long, on concrete abutments; and the Severn work was a concrete arch of 58½ feet span, built by Messrs. Gagne and Jennings. Mr. Geo. Hogarth of the School of Science, was inspector for the Tunnel Bridge on the Missassaga River north of Thessalon, a steel arch of 93 feet span, with a 60-feet steel trestle approach on concrete foundations. Mr. F. W. Robertson, of the School of Science, has made laboratory tests of cement for a number of works.

Obituary

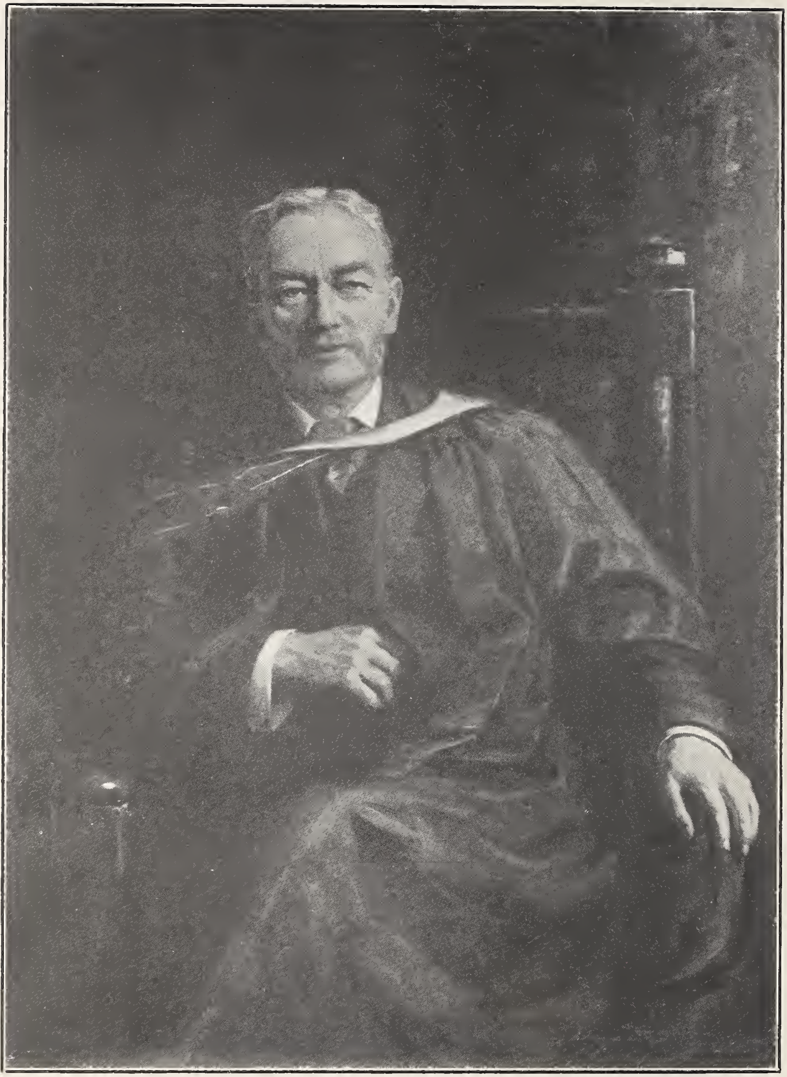
We regret to report the death of C. G. Milne, '92, late Chief Engineer of the Hamilton Bridge Works Co. Mr. Milne was one of the "School's" most brilliant and successful graduates. The profession, the university and the country suffer a distinct loss in his decease.

We have just received word of the death of Wm. Elwell, '02, who died on Sept. 3rd, 1909.

W. E. Cole, '08, one of the most promising men of the class of '08, died at his home at Lucasville on Dec. 31st, 1909.

We regret to report the untimely death of L. A. McLean, '08, on Feb. 14th, in Ottawa, Ont.

According to our custom, full obituary notices of these fellow-graduates will appear in the April issue.



J. Galbraith

From painting by J. W. L. Forster

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 MARCH, 1910 New Series Vol. 3, No. 5

THE ELASTIC ARCH.

DEAN GALBRAITH

Faculty of Applied Science and Engineering,

University of Toronto.

The subject of this paper is the theory of the graphical method used in connection with the design and computation of the elastic arch. The treatment is not intended to be complete but is directed specially to difficulties which have been brought to my attention by some of our graduates engaged in the design of reinforced concrete arches.

The method is originally due to Professor H. T. Eddy, now of the University of Minnesota, who published his results between 1876 and 1878. Professor Wm. Cain of the University of North Carolina was also one of the early contributors to the subject.

As a basis for the graphical method the general treatment of the arch will be first considered.

The arch is statically indeterminate, and in all treatments the three statical equations require to be supplemented by three others. On the assumption that the arch is inelastic the requisite equations are obtained by, in effect, the more or less arbitrary assumption of the positions of the centres of pressure at three cross-sections, e.g., the springing planes and the section at the apex. If on the other hand Young's modulus for the material be known, the conditions of elasticity and the methods of fixing the ends will furnish the three necessary conditions.

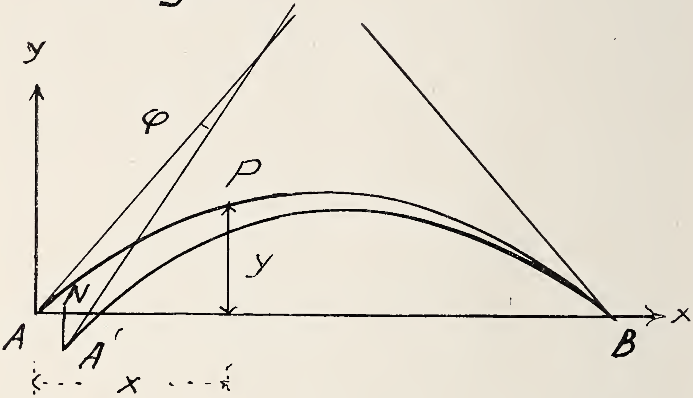
The Elastic Curved Beam.

The following theorems respecting the elastic curved beam will be stated without proof. (See Fig. 1.)

Let *A B* represent the axis of the curved beam when under a given loading, *A′ B* the form of the axis when unstressed. Let the two curves be made to coincide in position and direction at the end *B* then at the ends *A* and *A′* the curves will in general differ both in position and direction.

Assume as rectangular axes of reference *ABx* and *Ay* and let ϕ denote the angle between the directions of the tangents at A and A'. Let $AN = x'$, $NA' = y'$ be the co-ordinates of A', then it may be shown that

Fig. 1



$$1.\ \phi = \int^{B} \frac{M}{EI}\,ds; \quad 2.\ x' = \int_{A}^{B} \frac{My}{EI}\,ds; \quad 3.\ y' = -\int_{A}^{B} \frac{Mx}{EI}\,ds\,;$$

where x and y are the coordinates of P the current point on the curve AB, s the distance along the curve from A to P, M the bending moment at the cross-section at P, I the moment of inertia of the cross-section at P and E Young's modulus for the material of the beam. It is assumed that x' and y' are small compared with the greatest values of x and y respectively, and the lengths of AB and $A'B$ are considered equal.

The Elastic Arch with Fixed Ends.

It will be sufficient for the purpose of this paper to consider only the above arch. The loading will be assumed vertical and the form of the arch symmetrical with regard to a vertical through the apex.

In the case of a composite material such as reinforced concrete, EI will represent the composite expression $E_1\ (I_1 + nI_2)$.

The axis of the arch (often termed the neutral line) is the locus of the centres of gravity of the cross-sections of the arch if the material is homogeneous; in the case of reinforced concrete the cross-section of the steel is replaced by its concrete equivalent for the purpose of determining the centre of gravity. The axis of the arch and the cross-sections are at right angles to each other.

A bending moment M will be considered positive when it tends to make the arch concave upwards.

It is evident that in the case of the arch with fixed ends

$$1.\quad \phi = 0;\qquad 2.\quad x' = 0;\qquad 3.\quad y' = 0.$$

Thus in this arch the following conditions hold, viz:

$$1.\ \int^{B} \frac{M}{EI}\,ds = 0;\qquad 2.\ \int_{A}^{B} \frac{My}{EI}\,ds = 0;\qquad 3.\ \int_{A}^{B} \frac{Mx}{EI}\,ds = 0;$$

When the various quantities are not expressible as functions of x as is usually the case, the indicated integration must be replaced by graphical summation. In doing this the general principle involved is to make the subdivisions δs of the axis so short that the values of x, y, M, E and I corresponding to the middle points of the subdivisions may be used in the summations without producing serious error. The subdivision of the arch is thus more or less a matter of judgment. It should be founded on comparisons between the results of computations made with longer and shorter subdivisions.

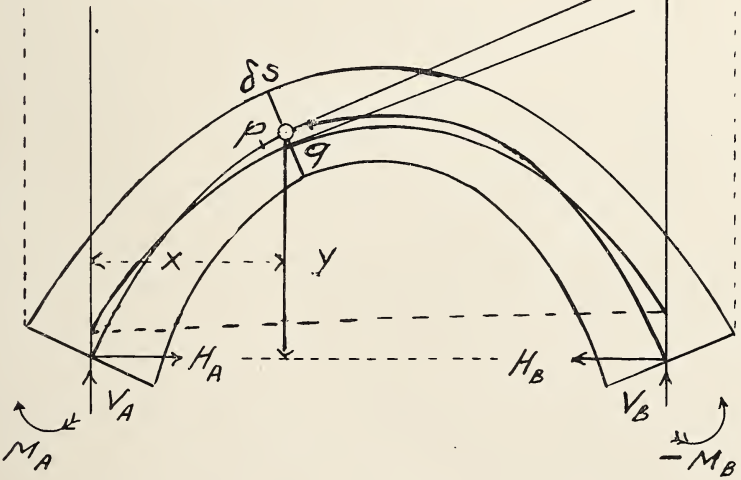
Subject to these considerations the following method of subdivision is sometimes used. The axis is divided by trial into subdivisions for which $\frac{\delta s}{EI}$ is constant or, if E is constant throughout the arch, for which $\frac{\delta s}{I}$ is constant.

The three conditions above found will then reduce to

$$1.\quad \Sigma M = 0;\qquad 2.\quad \Sigma My = 0;\qquad 3.\quad \Sigma Mx = 0.$$

omitting for the sake of brevity the limit symbols A and B.

Fig. 2



It follows at once from these equations that the values of M throughout the arch cannot all have the same sign.

Fig. 2 is a diagram of the arch showing a type subdivision δs, the coordinates x and y of its centre point, the supporting forces and couples V_a, H_a and M_a at the end A and V_b, H_b and $-M_b$ at the end B; the loading is not shown.

The bending moment M corresponding to any subdivision δs of the axis, that is the bending moment at the cross-section of the arch having its centre of gravity at the point x, y, may be considered as arising from the algebraic addition of three bending moments M', M'', M''' defined as follows:

M' is the bending moment due to the loading (see remarks) computed on the supposition that the arch is supported by vertical forces V'_a and V'_b as in the case of the freely supported horizontal beam.

M'' is due to the bending moments M_a and M_b at the end cross-sections. It is computed by assuming the arch to be maintained in equilibrium by fixing couples M_a and $-M_b$ at the ends together with a third couple composed of equal and opposite vertical forces V''_a, V''_b acting at A and B respectively.

M''' is due to the horizontal thrust H of the abutments.

From the conditions of equilibrium defining M'' and M''' it may be easily shown that

$$M'' = M_a + \frac{M_b - M_a}{l} x \text{ where } l \text{ is the span } AB.$$

also $M''' = -Hy$ assuming H to be thrust and positive.

$$\text{Thus } M = M' + M'' + M''' = M' + M_a + \frac{M_b - M_a}{l} x - Hy.$$

Then we have, if n denote the number of subdivisions δs of the axis,

$$1. \quad \Sigma M = \Sigma M' + nM_a + \frac{M_b - M_a}{l} \Sigma x - H\Sigma y = 0$$

$$2. \quad \Sigma My = \Sigma M'y + M_a\Sigma y + \frac{M_b - M_a}{l} \Sigma xy - H\Sigma y^2 = 0$$

$$3. \quad \Sigma Mx = \Sigma M'x + M_a\Sigma x + \frac{M_b - M_a}{l} \Sigma x^2 - H\Sigma xy = 0$$

the summations being taken from A to B.

Now $\Sigma M'$, $\Sigma M'y$, $\Sigma M'x$ and Σx, Σy, Σx^2, Σxy, Σy^2 may be computed from the loading and from the coordinates of the n points x, y, taken on the axis. Hence the above three equations will determine M_a, M_b and H to any degree of approximation desired. The approximation becomes closer as the lengths of the subdivisions are taken smaller.

M can now be determined from its equation for each of the n values of x.

H will denote an abutment thrust if positive, a tension if negative, so that the horizontal abutment reactions H_a and H_b become determined in both magnitude and sense.

Since the bending moment M_a and M_b are known the fixing couples M_a and $-M_b$ are determined.

NOTE—Lower case subscript letters in the text represent corresponding upper case letters in the diagrams.

Finally, the vertical abutment reactions V_a and V_b are determined from the equation of vertical resolved parts of the external forces and the equation of moments.

The positive senses adopted will be: For forces, upwards, to the right and clockwise; for stresses, thrust, shear lengthening the diagonal in a vertical rectangle from upper lefthand corner, bending producing concavity upwards.

On computing V'_a, V'_b and V''_a, V''_b from their definitions it will be found that

$$V_a = V'_a + V''_a ; \; V_b = V'_b + V''_b$$

The thrusts and shears at any cross-section of the arch may now be determined.

H having been determined we may write $M'' = Hy''$, $M' = Hy'$, also $M''' = -Hy$, thus $M = H\,(y'' + y' - y)$ and the three end conditions may be written:

1. $\Sigma\,(y'' + y' - y) = 0$
2. $\Sigma\,(y'' + y' - y)\,y = 0$
3. $\Sigma\,(y'' + y' - y)\,x = 0$
4. Where $y'' = \dfrac{M''}{H} = \dfrac{M_a}{H} + \dfrac{\dfrac{M_b}{H} - \dfrac{M_a}{H}}{l}\,x$
5. and $y' = \dfrac{M'}{H}$

a result which will be used in the explanation of the graphical method.

This completes the resumé of the general method of computing the elastic arch with fixed ends.

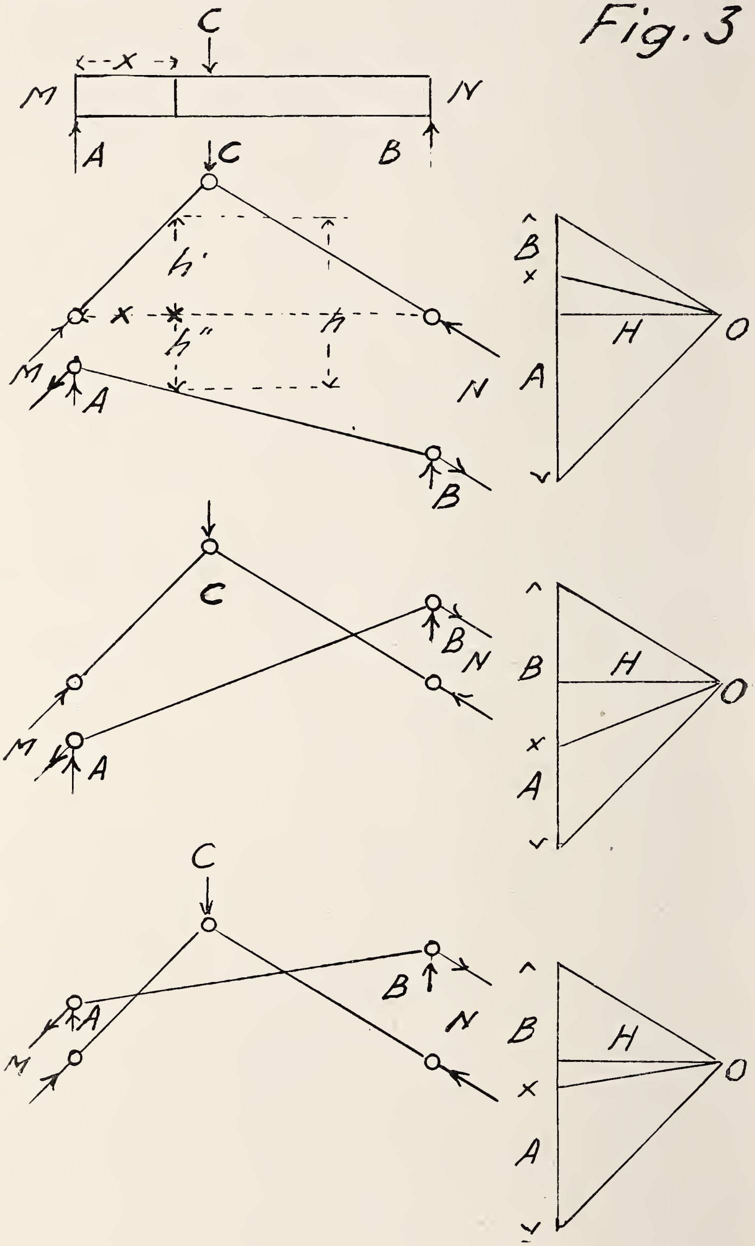
Graphical Computation.

It may be useful to begin with a simple problem involving end couples.

Thus suppose a beam (see Fig. 3) supporting a single load C and acted on by given couples of moments M and N at the ends. Let it be required to determine graphically the supporting vertical reactions A and B. Three cases are worked out in the figure.

Construct the polar diagram and the funicular or equilibrium polygon for the load; then lay off the couples having the moments M and N using as forces the end forces acting on the arms of the funicular polygon of the load and forces equal and opposite to these as shown in the diagrams. The line joining the intersections of the latter forces with the end verticals will be the closing line or closing arm of the complete funicular polygon. A more accurate method of constructing the end points of the closing line is to lay off vertical ordinates in the proper senses (shown in the figure) from the end points of the funicular polygon of the loading, viz., the ordinate $\frac{M}{H}$ at the left and the ordinate $\frac{N}{H}$ at the right-hand end. H is the horizontal pole distance in pounds.

Fig. 3



A line drawn from the pole O in the polar diagram parallel to this closing line will divide the vertical load line into two portions representing A and B as shown.

It is evident that if the end couples be altered by equal absolute amounts the reactions A and B will remain unaltered, for the new closing line will be parallel to the old.

The bending moment at any section x is Hh when h is the vertical ordinate drawn from the closing line to meet the funicular polygon of the loading.

Writing $h = h' + h''$ where h'' runs from the closing line to meet the line joining the end points of the funicular polygon of the loading, we shall have Hh' representing the bending moment at x if no end couples act and Hh'' the bending moment due to the end couples M and N if no loading exists and if equilibrium be maintained by equal and opposite vertical reactions A'' and B'' at the ends. It is evident that if A' and B' be the vertical end reactions due to the loading alone $A' + A'' = A$ and $B' + B'' = B$; also $Hh'' = M + \frac{N - M}{l} x$ where l represents the span.

The complete funicular polygon considered as a jointed frame is thus divided on account of the end couples into two parts, each part being in equilibrium under external forces. Thus no stress exists between these parts when considered as parts of a jointed frame.

If the forces of the end couples be represented in the polar diagram and the funicular polygon be drawn in the ordinary way the portion of this polygon between the end verticals is the funicular polygon shown in Fig. 3.

Construct (see Fig. 4) the funicular or equilibrium polygon $A' C' B'$ for the vertical loading by means of a polar diagram having any convenient pole. Any suitable divisions of the arch may be used for this purpose since this diagram is entirely independent of the variation of the quantity EI which determines the n subdivisions δs used in the summations 1, 2, 3. The annexed diagram is drawn on the supposition that the subdivisions are infinitely small. A', B' are in the same verticals as A, B.

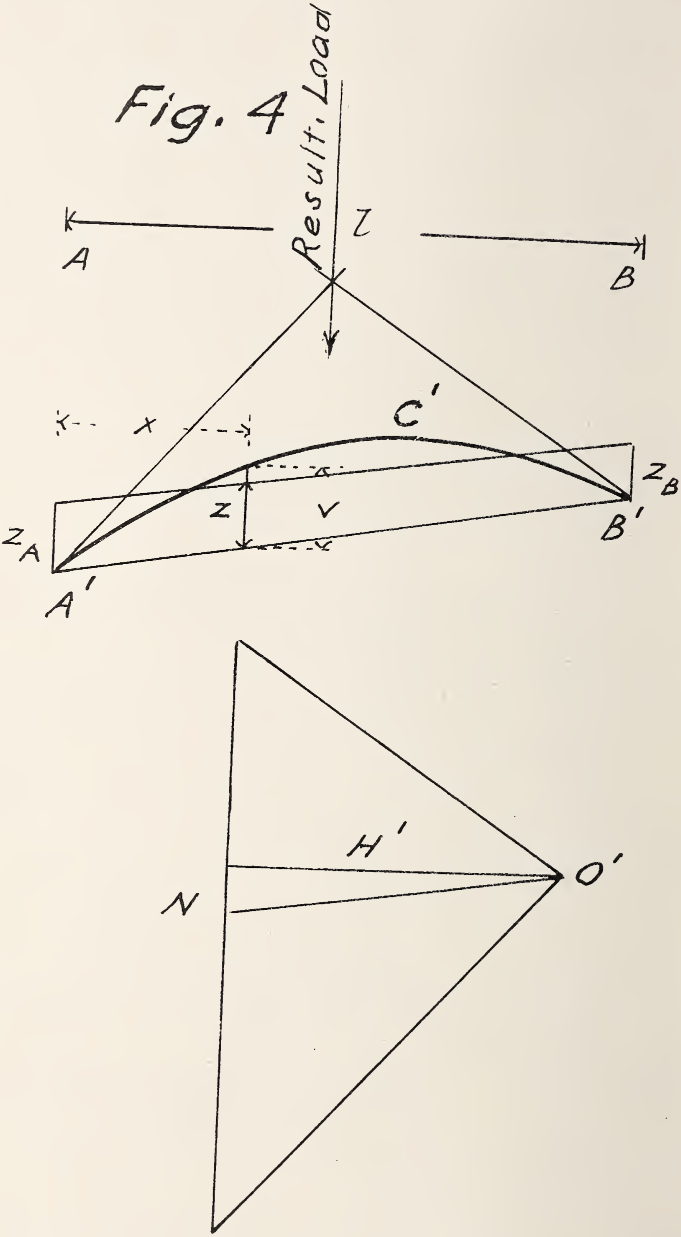
If then x denote the abscissa of the middle point x, y, of one of the n subdivisions δs of the axis and v the ordinate of the equilibrium polygon corresponding to x the bending moment corresponding to this point due to the vertical loading will be given by $M' = H'v$ where H' is the horizontal pole distance in pounds. (See remarks.)

Now construct a straight line on the same base $A' B'$, the ordinates z of which for each value of x are so related to the ordinates v of the above equilibrium polygon that
$\Sigma z = \Sigma v$ and $\Sigma zx = \Sigma vx$ summing from A' to B'; thus
$\Sigma(v - z) = 0$; $\Sigma(v - z)x = 0$.

It must be noticed that the above summations do not include any ordinates except those corresponding to the values of x for the middle points of the n divisions δs of the arch.

Evidently $z = z_a + \frac{z_b - z_a}{l}x$ where z_a and z_b represent the end ordinates of the z line.

Fig. 4



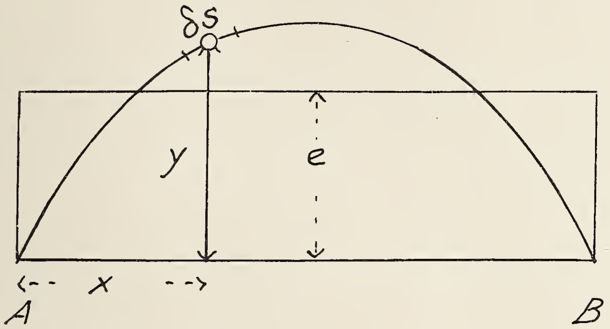
In a similar manner construct (see Fig. 5) from the n ordinates y of the axis of the arch a straight line of which the ordinates e for the several values of x fulfil the conditions

$$\Sigma e = \Sigma y;\ \Sigma ex = \Sigma yx$$

and thus

$$\Sigma(y - e) = 0;\ \Sigma\,(y - e)\,x = 0$$

Fig. 5



Since the axis is symmetrical with regard to its apex evidently e will be constant for all values of x and will fulfil the condition

$$ne = \Sigma y \text{ or } e = \frac{\Sigma y}{n}$$

In this case the condition $\Sigma ex = \Sigma yx$ is fulfilled necessarily and is therefore not an independent condition; if not obvious this may be shown as follows:

From symmetry:

$$\Sigma ex = \Sigma e(l - x) = \Sigma el - \Sigma ex \text{ where } l = \text{span } AB.$$

$$\therefore\ 2\Sigma ex = \Sigma el = nel$$

$$\therefore\ \Sigma ex = \frac{nel}{2}$$

also $\Sigma yx = \Sigma y(l - x) = \Sigma yl - \Sigma yx$

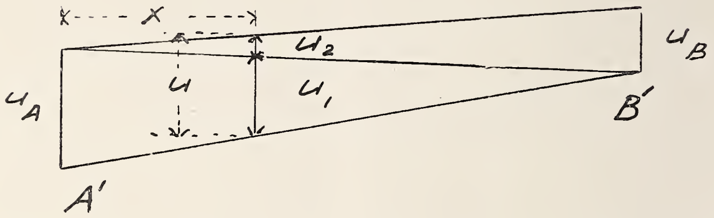
$$\therefore\ 2\Sigma yx = \Sigma yl = l\Sigma y = lne$$

$$\therefore\ \Sigma yx = \frac{lne}{2}$$

$$\therefore\ \Sigma yx = \Sigma ex.$$

Graphical Computation of z. (See Fig. 6.)

Fig. 6

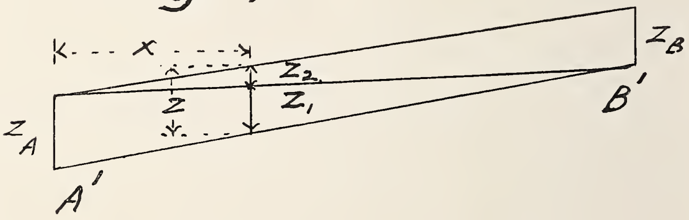


Draw any straight line to base A' B' and let the ordinate corresponding to abscissa x be represented by u; draw the diagonal shown cutting the ordinates u each into two parts, a lower u_1 and an upper u_2 so that $u_1 + u_2 = u$.

Then write $\bar{x}_1 = \frac{\Sigma u_1 x}{\Sigma u_1}$; $\bar{x}_2 = \frac{\Sigma u_2 x}{\Sigma u_2}$

From the properties of the triangle it is evident that the values of $\bar{x}_1$ and $\bar{x}_2$ remain unchanged whatever be the values of u_a, u_b, hence the above construction will give the values of $\bar{x}_1$ and $\bar{x}_2$ for the z diagram (Fig. 7) even though the values of z are as yet unknown.

Fig. 7



Then drawing a similar diagonal in the z diagram we have

$$\frac{\Sigma z_1 x}{\Sigma z_1} = \bar{x}_1 \qquad \frac{\Sigma z_2 x}{\Sigma z_2} = \bar{x}_2$$

Also $\Sigma z_1 x + \Sigma z_2 x = \Sigma z x = \Sigma v x$ by hypothesis
and $\Sigma z_1 + \Sigma z_2 = \Sigma z = \quad = \Sigma v$ by hypothesis.
$\therefore\ \bar{x}_1\, \Sigma z_1 + \bar{x}_2\, \Sigma z_2 = \Sigma v x$; $\Sigma z_1 + \Sigma z_2 = \Sigma v$
which equations give the unknowns Σz_1 and Σz_2

$$\text{thus } \Sigma z_1 = \frac{\bar{x}_2 \Sigma v - \Sigma v x}{\bar{x}_2 - \bar{x}_1} \quad ; \qquad \Sigma z_2 = \frac{\Sigma v x - \bar{x}_1 \Sigma v}{\bar{x}_2 - \bar{x}_1}$$

The following transformation may be more convenient for computation:

Write $\Sigma vx = \bar{x}\Sigma v$ and compute $\bar{x}$

$$\text{Then } \Sigma z_1 = \frac{x_2 - \bar{x}}{x_2 - x_1}\Sigma v\ ;\quad \Sigma z_2 = \frac{\bar{x} - x_1}{x_2 - x_1}\Sigma v.$$

Now from the properties of a triangle it is evident that

$$z_a = \frac{\Sigma z_1}{\Sigma u_1}u_a \text{ and } z_b = \frac{\Sigma z_2}{\Sigma u_2}u_b$$

so that substituting in these expressions the values already found for Σz_1 and Σz_2 the values of z_a and z_b become known.

The z diagram can now be constructed and the value of z determined by measurement or computation for each value of x.

The constructions Fig. 6 and Fig. 7 are usually made directly on Fig. 4.

It is evident that $\dfrac{u_a}{\Sigma u_1} = \dfrac{u_b}{\Sigma u_2}$ and that the u line may as well be drawn parallel to $A'\ B'$ and one triangle computed instead of two.

Analytical Computation of z.

z may be computed analytically as follows:

$$\Sigma z = \Sigma v$$
$$\Sigma zx = \Sigma vx$$
$$z = z_a + \frac{z_b - z_a}{l}x$$

Substituting from the last equation in the first

$$nz_a + \frac{z_b - z_a}{l}\Sigma x = \Sigma v$$

Substituting similarly in the second equation

$$z_a\Sigma x + \frac{z_b - z_a}{l}\Sigma x^2 = \Sigma vx$$

$$\text{thus } \left(n - \frac{\Sigma x}{l}\right) z_a + \frac{\Sigma x}{l} z_b = \Sigma v$$
$$\left(\Sigma x - \frac{\Sigma x^2}{l}\right) z_a + \frac{\Sigma x^2}{l} z_b = \Sigma vx$$

which equations will give z_a and z_b in terms of the known quantities l, n, Σx, Σv, Σx^2, Σvx.

z may then be computed for each value of x.

$$\text{The results are } z_a = \frac{\Sigma v\Sigma x^2 - \Sigma x\Sigma vx}{n\Sigma x^2 - (\Sigma x)^2}$$
$$z_b = \frac{\Sigma v.\Sigma x^2 - \Sigma x.\Sigma vx + l\,(n\Sigma vx - \Sigma x\Sigma v)}{n\Sigma x^2 - (\Sigma x)^2}$$
$$z = \frac{\Sigma v\Sigma x^2 - \Sigma x\Sigma vx + x\,(n\Sigma vx - \Sigma x\Sigma v)}{n\Sigma x^2 - (\Sigma x)^2}$$

The z's and e's having been determined the next step is to compute the summations

$$\Sigma(v - z)y = P \qquad \Sigma(y - e)y = Q$$

Then writing $v' = \frac{Q}{P} v$; $z' = \frac{Q}{P} z$ we have $\Sigma z' = \Sigma v'$; $\Sigma z'x = \Sigma v'x$. Therefore

$$\begin{array}{ll} \Sigma(v' - z') = 0 & \Sigma(y - e) = 0 \\ \Sigma(v' - z')y = Q & \Sigma(y - e)y = Q \\ \Sigma(v' - z')x = 0 & \Sigma(y - e)x = 0 \end{array}$$

Hence by subtraction

1′ $\quad \Sigma(e - z' + v' - y) = 0$

2′ $\quad \Sigma(e - z' + v' - y)y = 0$

3′ $\quad \Sigma(e - z' + v' - y)x = 0$

in which $e - z' = e - \left\{ z'_a + \frac{z'_b - z'_a}{l} x \right\}$

4′ That is $e - z' = e - z'_a + \frac{e - z'_b - (e - z'_a)}{l} x$

5′ $\quad v' = \frac{Q}{P} v = \frac{M'}{\frac{P}{Q} H'}$

Comparing these equations with the equations already established, viz:

1. $\quad \Sigma(y'' + y' - y) = 0$

2. $\quad \Sigma(y'' + y' - y)y = 0$

3. $\quad \Sigma(y'' + y' - y)x = 0$

4. $\quad y'' = \frac{M_a}{H} + \frac{\frac{M_b}{H} - \frac{M_a}{H}}{l} x$

5. $\quad y' = \frac{M'}{H}$

we see that both sets involve the quantities l, x, y and M' in the same way and that $e - z'_a$, $c - z'_b$, $\frac{P}{Q} H'$ of the first set and $\frac{M_a}{H}$, $\frac{M_b}{H}$, H of the second set are respectively involved in the same way.

Consequently

$$e - z'_a = \frac{M_a}{H} \; ; \; e - z'_b = \frac{M_b}{H} ; \quad \frac{P}{Q} H' = H$$

In other words the graphical construction gives the true values of the horizontal thrust and the bending moments at the ends of the arch.

Fig. 8 is now constructed from Fig. 4 by making $v' = \frac{Q}{P} v$, $z' = \frac{Q}{P} z$ and making the upper line of the z' diagram horizontal, its length being equal to l the span AB.

Fig. 8

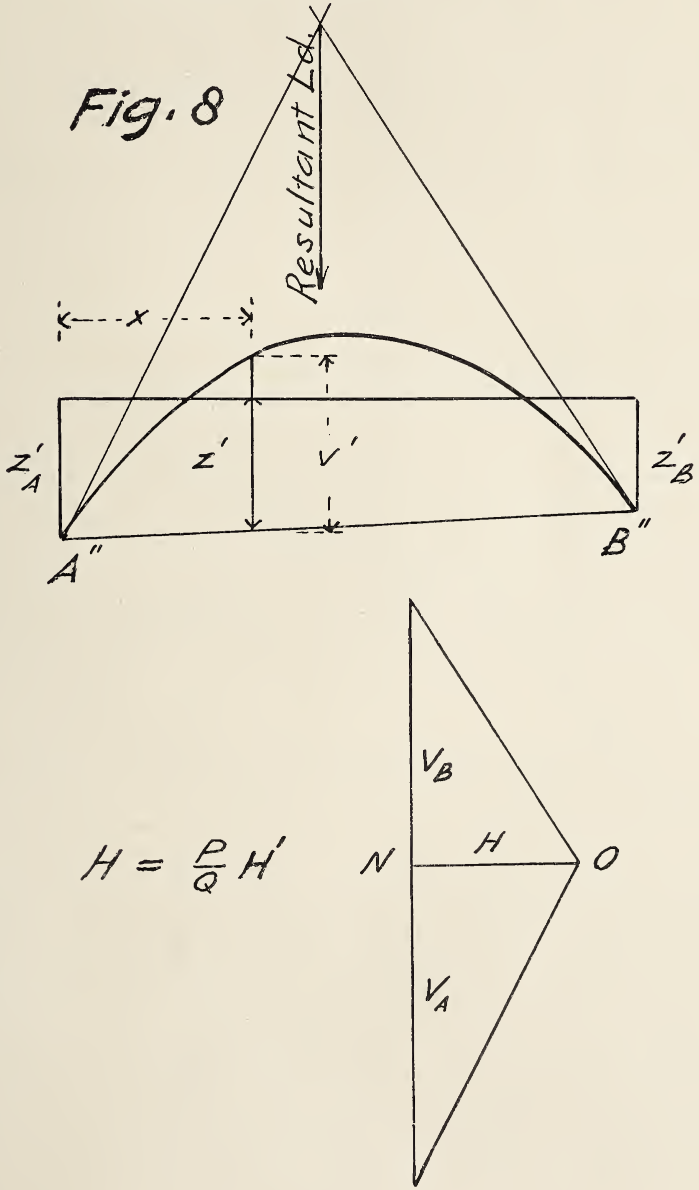
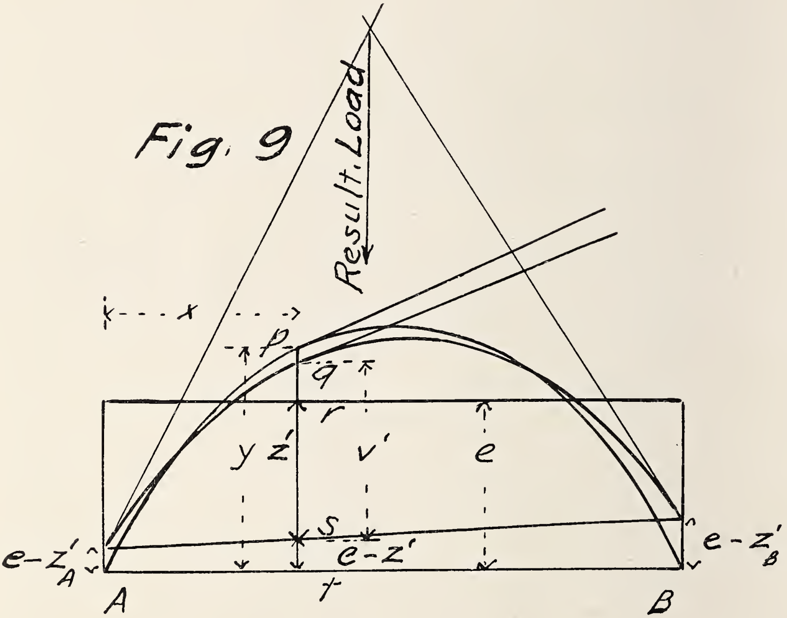


Fig. 9 is now constructed by applying Fig. 8 to Fig. 5 so that the horizontal z' line of the former coincides with the horizontal e line of the latter.

Draw the ordinate in Fig. 9 for abscissa x and let it cut the various lines in the points p, q, r, s, t. Evidently $ts = e - z'$; $sq = v'$ and $tp = y$. Thus $M = (ts + sq - tp)H = -qp \times H = pq \times H$. Hence the ordinate corresponding to M for any section x is that part of the ordinate at x intercepted between the axis of the arch and the curve of moments, reckoned positive if drawn upwards from the axis. In the figure this ordinate is negative.

The moment M'' due to the end couples M_a and $-M_b$ being equal to $(e - z')H$ or $He - Hz'$ may be analyzed as follows:

Fig. 9



The bending moment $-Hy$ due to the horizontal thrust of the abutments generates an opposing bending moment He due to the fixed directions of the axis at the abutments; the bending moment Hv' due to the vertical forces generates an opposing bending moment $-Hz$ due also to the fixed directions at the abutments and the sum of these $He - Hz'$ is the total bending moment due to the fixed directions at the abutments.

There are thus two bending moments Hv' and $-Hz'$ due to the vertical system of forces and two bending moments $-Hy$ and He due to the horizontal system of forces. The sum of these four moments is the resultant bending moment M.

The horizontal thrust H is itself due to the vertical system of forces, being caused by the action of the latter on the elastic body of the arch which is prevented from spreading by the fixed abutments.

Vertical Reactions at A and B.

These are obtained from the polar diagram Fig. 8. It is constructed as follows: from the pole O' Fig. 4, draw a line $O\ N$ parallel to the closing line (the z line) to meet the load line, and transfer the point N so obtained to the load line of the polar diagram of Fig. 8. From N in the latter diagram lay off horizontally a line representing the true horizontal thrust H; the end O of this line represents the correct position of the pole in Fig. 8 and the point N divides the load line into the portions representing the vertical reactions V_a and V_b as indicated. The reasons are as follows:

The z line in Figure 4 is the closing line due to the combination of the loading with end couples of moments $-H'z_a$ and $+H'z_b$; these moments by construction are equal to $-Hz'_a$ and $+Hz'_b$, therefore the vertical reactions in the combination represented in Fig. 8 must be the same as in the case of Fig. 4. Now the closing line in Fig. 8 is horizontal; hence if H be laid off horizontally from N in Fig. 8 as shown, the proper position of the pole O will be found for the combination shown in Fig. 8. The true end moments indicated in Fig. 9, viz., $M_a = H(e - z'_a)$ and $-M_b = -H(e - z'_b)$ are not the same as the end moments in the case of Fig. 8 which are $-Hz'_a$ and $+Hz'_b$. However, they also give a horizontal closing line, viz., the base $A\ B$ of Fig. 9, so that the position of N in Fig. 8 indicates the true vertical end reactions. See discussion of Fig. 3.

Thrusts and Shears at a Cross-Section.

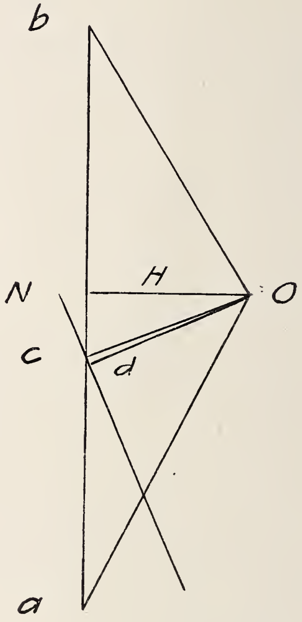
Consider the cross-section corresponding to x.

In the polar diagram of Fig. 8 let $c\ a$ (see Fig. 10) represent the load between the verticals at A and x; join $O\ c$; draw $c\ d$ parallel to the cross-section at x and drop the perpendicular $O\ d$ on $c\ d$. Then it is evident that $c\ O$ represents the oblique thrust on the cross-section, $c\ d$ its tangential resolved part or the shear (negative by the rule of signs) and $d\ O$ the normal thrust.

The position of the point of action on the cross-section, of the thrust $c\ O$, is obtained by drawing the tangent to the v' curve at the point corresponding to x to meet the cross-section in question. It nearly coincides with the point of intersection of the v' curve with the cross-section.

Evidently $O\ d$ is parallel to the tangent to the axis at p and $O\ c$ parallel to the tangent to the v' curve at q in Fig. 9 or Fig. 2.

Fig. 10



Remarks.

In this investigation the shortening of the elastic arch arising from the axial thrusts at the various cross-sections has not been taken into consideration nor the effects due to temperature changes.

The loading has been assumed to be vertical; that is to say no horizontal or spandrel reactions due to the load have been considered. The horizontal thrust is thus constant from abutment to abutment.

In computing the bending moment M' due to the loading, the load from the abutment up to the section in question has been assumed to be the weight of the material (including that in the arch itself) which lies between the verticals drawn through the axial points of the springing section A or B and of the section considered; similarly the whole load on the arch has been assumed to be the weight of the material (including that in the arch) lying between the verticals through the axial points A and B at the springing planes. The weights of the portions of the arch outside of these verticals and their superincumbent loads have therefore not been included in the computation.

The errors due to this method of computing the bending moments due to the vertical loads, become less, the flatter the arch is, that is the more nearly it approaches in form the horizontal beam. Similarly in a given arch the errors are least at the apex where the axis is horizontal, and greatest at the abutments.

The end tangents shown in Figs. 4 and 8 evidently give the lines of action of the abutment reactions for the assumed system of loading.

The abutments are assumed to be inelastic and rigid.

REFERENCES:

Cain—"Theory of Steel-Concrete Arches, etc."

Buell and Hill—"Reinforced Concrete."

Morley—"Strength of Materials."

COAL AND THE LOCOMOTIVE.

GEORGE S. HODGINS (S.P.S., 1881).

Managing Editor, Railway and Locomotive Engineering.

It has been poetically said that coal is but the imprisoned sunbeams of the past, and although this may not be literally correct, yet it is a statement which embodies something of truth. Geological research has established the vegetable origin of coal, and the original plants, from the remains of which our coal was formed, drew their substance from the luxuriant soil of that far-distant epoch in which they lived. They separated out carbon and liberated oxygen under the genial influence of the sunshine of the very remote past. The predominant feature of the process here alluded to, was the chemical transformation from soil and air, under the sun's beams and by reason of the heat derived from that source.

George S. Hodgins,
Managing Editor, Railway and Locomotive Engineering.

Speaking of the Palaeozoic age and of the vegetable forms from which our coal is derived, Hugh Miller says, "In no other age did the world ever witness such a flora; * * * A rank and luxurious herbage cumbered every foot-breadth of dank and steaming soil, and even to distant planets, our earth must have shone through the enveloping clouds with a green and delicate ray." The growth of the plant was then for the most part a chemical process; a separation of elements and a union of others. For our purpose it may be summarized as the separation of the oxygen from the carbon and from the hydro-carbons of the plant, and the long burial of the fallen forests did not disturb these conditions as established when the plant lived. The solar energy effected the chemical changes which are reversed when coal is burned to-day.

Energy has been defined as the ability to do work, and energy may be present in the active or in the passive form—it may be potential or it may be kinetic. The passive or potential form can be seen when the hammer of a pile-driver is raised aloft, and hangs motionless and inert at the top of the guides. The attraction of gravity acts upon it, but until the detent is thrown out, the hammer cannot do work. It has, however, the potential energy of position with reference to the pile below. So it is with coal. It has not to be endowed with its energy by mechanical means like the hammer of the pile-driver. It possesses, by virtue of the solar energy of a by-gone age, the potential energy of chemical separation, and awaits only the presence of appropriate conditions (as the hammer waits for the detent) to burst into flame, and give back, by the union of the long separated oxygen and carbon, the energy stored up in its substance in the days when the earth was young.

This coal, heaped upon the tender of a locomotive and containing potentially the slowly accumulated energy of an era when mankind did not exist, yet finds the necessary temperature conditions, for liberating its stored up energy when thrown into the firebox. Here in the flame-storm above the white-hot fuel, the concentrated effects of solar energy are given off in the form of radiant heat and glowing gas which beat against the side and back sheets of the firebox, strikes up against the crown sheet, and rush against the tube sheet and through the flues. The steel plates of the firebox quickly transmit the radiant vibrations—this mode of molecular motion which we call heat, and if one may so say, these vibrations stream through the plates and out into the mass of water in the boiler.

Here the molecular agitation set up in the plates communicates itself to the water, and so intense are these heat vibrations, that the water ceases to retain the liquid form. Its particles are moved about with such exceeding rapidity that they are compelled to assume the gaseous state in order to give scope and freedom to the enormously rapid motion which they are compelled to adopt. Thus is formed what we call steam. The gaseous form of matter demands greater space for the swing and sway of its atoms, than is required in the liquid state. This demand for increased space, in a confined vessel like a boiler, produces a violent action of the particles, with more frequent and more powerful collisions between each particle. This phenomenon, we recognize as pressure. It therefore becomes apparent that the sun's action, directed upon the plant life of this earth, at a period so remote that the mind cannot grasp it, has waited through many ages to be so liberated and so employed, as to produce for us, what we prosaically describe as steam under pressure.

The opening of the locomotive throttle valve allows steam under pressure to flow through the dry pipe, down the branch pipes to the steam chests and thence to the cylinders. Here the vibratory action, deadened somewhat by hammering upon the walls and passages it has encountered and traversed, is a little less active, and we speak of it as having slightly cooled. Nevertheless, it continues a bombardment on piston and cylinder cover, and on the cylinder walls, as the vibrating particles of steam dash hither and thither in their endeavor to expand or run the full extent of their normal excursions. The fixed cylinder-cover remains unmoved, save that its particles imbibe the vibrations of the steam particles and so grows hot. The piston, however, capable of molar motion, is subjected to the myriad blows of the dancing steam particles and the piston gives way and slowly recedes before the gaseous onslaught of a billion atoms.

The piston moves back as a whole, though its particles are agitated like those of the cylinder cover, and the moving piston concentrates its action on the piston-rod. The rod forces the crosshead to move backward and this in turn communicates its motion to the connecting rod of the engine, and this being fastened to the crank-pin pushes it backward on the lower half of its course; the driving wheel revolves, and the engine moves ahead.

Here the curious phenomenon of the push on the crank-pin on its lower half-circuit, causing a forward motion of the engine, makes its appearance. Ordinarily if an object is pushed in any given direction, it moves in that direction, yet here we have a well-defined backward motion of the crank-pin producing a forward movement of the engine. The crank-pin is pushed backward on the lower half of its course and if this push could be given by a squad of men standing on the ground, the engine would move backward and not forward as we know it does. The reason why the engine moves forward when the crank-pin below the axle, is pushed backward by the agency of steam can be explained by a little alteration of the mechanism.

If the "big end" of the connecting rod was uncoupled from the crank-pin and placed so that it would rest against one edge of a tie on the track, the backward push of the steam on the piston would force the crosshead back, and the engine would go ahead. It would then be very evident that the connecting rod itself, or indeed the piston and crosshead, did not move at all, and the question arises from whence comes the motion of the engine, for it undoubtedly moves forward? We have now to return to a consideration of the bombarding action of the particles of steam in the cylinders. The bombardment of steam particles took place not only on the piston but on the walls of the cylinder and on the front cover. This incidentally shows that the pressure of steam acts equally in all directions. As the piston is held stationary by the connecting-rod with big end against the tie, the pressure of steam acting on the front cover moves it ahead. The cover being rigidly connected to the cylinder, and the cylinder being bolted to the frame; the cover, cylinder and frame together move forward, and as it were, draw the cylinder over the piston, and the forward movement of the frame carries forward the driving axle-box, and the wheel rolls forward. In this case the engine would only move forward a distance equal to the stroke.

When the connecting rod is attached to the crank-pin in the usual way and the pin acted upon by the backward pressure of the connecting rod, the wheel becomes practically a lever. of the second class, where the fulcrum is at the point of contact of wheel and rail, the power is applied at the axle box, and the resistance is at the crank-pin. The arm of the power is the distance from the axle-box to the rail, and the arm of the resistance is from the crank-pin to the rail. The power and the resistance being equal the greater length of the power arm causes it to predominate and compel the engine to go ahead. In this case the fulcrum constantly shifts, a new lever being, as it were, formed momentarily. The engine will now move a distance equal to the half circumference of the wheel.

As soon as the crank-pin comes above the centre of the wheel and enters upon its course above the axle, the piston is pulled forward and the back cylinder head and the frame are thrust back. The wheel again becomes a lever of the second-class with fulcrum at the rail, power applied to the pin, and the resistance at the axle. The leverage being now in favor of the pin by reason of its greater distance from the rail, than that from axle to rail, the force on the longer arm of the power prevails, and the engine continues to move forward. In the former case we spoke of the power being applied at the axle, and the resistance at the pin, when on its lower half circuit, in order to maintain the idea of the power producing the result observed. In this case with pin on its upper half circuit, we speak of the power being applied to it and the resistance as applied at the axle, for the same reason. In these two examples, for sake of uniformity, the arm of the power is in each case, taken as greater than that of the resistance. The predominence of the power, when viewed in this light, is apparent.

When examining the Stephenson link motion and D-slide valve of an ordinary 4-4-0 type of locomotive, one might be inclined to enquire why an engine starts in a predetermined direction from, say, the forward dead centre. If, for example, the right-hand piston is at the beginning of its backward stroke, and the reverse lever is in the extreme forward notch, the slide valve will be found to be open, the amount of full-gear lead, say 1-8 of an inch. If the reverse lever is moved backward to the centre of the quadrant, the valve opens the port further, until it reaches its mid-gear lead position. This is greater than the full-gear lead. If the motion of the reverse lever is proceeded with to the back notch, the valve moves to its full-gear lead position, which is, other things being equal, 1-8 of an inch. The question is, if steam be admitted to the cylinder under these conditions, which way will the engine move? Valve and piston are in the same position with reverse lever full forward or full back.

The obvious answer is that if we had only one side of the locomotive to deal with we might not make a very satisfactory start. The point, however, to remember is that if the reverse lever was in full forward gear and the engine attempted to go backward the small lead opening would be very quickly closed, but if the engine elected to go forward, the lead opening would be increased very promptly. At the time the right side of the engine is in full gear ahead, the left side of the engine, having its crank-pin set a quarter turn behind the right pin, is on the top quarter and the left slide valve is open so that steam can only enter the left cylinder behind the piston. Under these circumstances the engine can only go forward. The slightest motion in that direction places the right crank-pin below the centre and the engine moves ahead as a natural consequence.

We have, up to this point, endeavored to trace, though in a somewhat disjointed way, the present-day action of the long-gone-by power of the sun, until it re-appears in the motion of a modern locomotive. We have seen how the carbon and oxygen, united again in the firebox, gave back as heat, the energy which had originally been expended to separate them, and that the potential energy resident in the coal was not destroyed through the lapse of time. The accumulation of this potential energy by the plants was slow and gradual. Each one germinated, grew, waxed great and fell. Myriads of trees followed in the tardy process and were at length overthrown. The submerging, burying, solidifying of the forests required a period of time to which recorded history is as but yesterday. In the slow march of the years they were crushed down and built together into what we call coal. This age-long process has stored up for us, unused, the energy we now employ with prodigality as the spendthrifts of the ages. That a man may travel swiftly from Toronto to Hamilton there has been drawn from the storehouse of nature a supply of the once radiant energy of the sun, slowly gathered by plant life through long stretches of a distant past, and it is faithfully given back in the form of motion. The sun-god is still the power that speeds our trains over the iron way.

ENGINEERING IN CANADA.

WALTER J. FRANCIS, M.C.Soc.C.E., M.A.Soc.C.E.

Canadian Correspondent, The Engineer, (London),

It has been said that there is nothing new under the sun. Whatever there may have been in the untold ages of the past it is certain that for a score of centuries the human race did without countless things that to-day are considered necessities. From the days of Nebuchadnezzar, King of Babylon, to the time of George IV of England, and for even a longer period we did pretty much the same things in the same way, and the trifling changes made were due to the influence of climate more than to any other cause. The battles depended largely on the work of the individual soldiers in hand-to-hand encounter. Horses and men provided the sole means of transportation and communication by land. The only source of power in nature that was applied to the use and convenience of man was the wind —to grind corn and to propel ships. Nevertheless it was during these years that literature, architecture and art reached perfection so great that they stand to-day the masterpieces of the world, the examples which our most ardent students seek to copy, and the pride of the most cultured and scholarly.

The remarkable skill attained by the masons in pyramid construction, in the building of temples and, later, in cathedrals may account in some measure for the noteworthy accomplishments of the Romans in waterworks and roadmaking two thousand years ago, all being work in stone and consequently somewhat related in character.

It remained for the nineteenth century, however, to make advances along other lines that have revolutionized the world, advances which in effect may yet surpass the most sanguine dreams of the optimistic prophet. To-day people do things in a matter-of-fact way that would have been considered impossible fifty years ago. Who can foretell for ten years, say, what will be the developments in aerial navigation, in electricity with its countless interests, in chemistry or in surgery? With one exception surgery has advanced more than any other branch of learning in these latter days. That exception is engineering. Mankind must thank engineering for converting luxuries into necessities. Engineering has given the world its factories, its telegraphs, its steamships and its railroads. Even architecture, in spite of her ancient dignity, must acknowledge that her devotees are enabled to cope with the building problems of the day because engineering has produced the tall framework of steel and of reinforced concrete. Surgery, for whose youthful vigor the discovery of anaesthetics is responsible, may yet resort to electricity to render her subjects insensible to pain if one may judge of the articles in the current magazines. Our universities, so long sacred to classics and mathematics, are now unable to accommodate the young men who throng there to study applied science.

Walter J. Francis, C.E.,
The Engineer, (London).

It would be difficult indeed to eliminate the engineer from the world problems of to-day. He it is who develops the mining and produces the steel that spans our rivers, that forms a wonderful grillwork over our continents, that makes possible on our oceans the multitude of floating fortresses and cities, and that constitutes the myriad of machines which by their ingenuity compel us to stand in awe and admiration. He it is who harnesses the Niagaras of the world to provide us transportation, to transform the night of our cities into noonday, and to turn the wheels of commerce. The engineer has developed the details of sanitation and has thus bestowed upon mankind one of the greatest of blessings. Take from us the telegraph, the telephone and the wireless; take from us the typewriter, the talking-machine, the bicycle and the automobile, and we shall appreciate a little more fully some of the efforts of the engineer. The four words which comprehend "engineering" more completely than any others perhaps are power, manufacturing, communication and transportation. These four words embrace a very large part of the civilization of the present time. The greatest of these is transportation.

The charms of Canada, fairest daughter of the Mistress of the Seas, have naturally not been lost on the engineer. The growth of the two has been contemporaneous. Let us for a short time consider what has already been done, after which some remarks pertaining to the future of engineering in Canada may not be out of place.

It is not many years ago that Canada was described in almost the same words by which the schoolboy was taught to define a line—length without breadth. The land area bounded by the Atlantic and the Pacific, and lying between the 49th parallel and the North Pole, is very great; but most of it is still ruled by the unfettered hand of Nature, only a comparatively narrow strip along the southern boundary being settled and devoted to cultivation. The Maritime Provinces being accessible by sea from the old land were the first to be populated. The navigators continuing up the mighty St. Lawrence are responsible for the settlement of Quebec and the old part of Ontario. The needs of the district were not great but they taxed the engineering and financial resources to their utmost in providing the railways which now constitute a considerable part of the Grand Trunk System, and the artificial waterways that were constructed to overcome the obstructions in navigation in the Niagara River and along the St. Lawrence. The earliest noteworthy achievements in bridge building were the Victoria Tubular Bridge, built by Stevenson & Ross in 1859 over the St. Lawrence at Montreal, and the Suspension Bridge at Niagara built about the same time by Roebling. The opening up of Manitoba in the early seventies marked the first progress westward. The great Northwest was a desert littered with buffalo bones.

The wheat fields were as yet undreamed of. Fort Garry, by which name Winnipeg was first known, was a small village and Hudson Bay Company's post. Then came the building of the first transcontinental railway, the greatest railway problem the engineer had yet been called upon to solve. How well it was done has been amply proved by its subsequent use. To the construction of the Canadian Pacific Railway Canada owes the colonization of the West. The settlers poured in, the wheat fields were developed and Nature assisted by the farmer provides a volume of freight that taxes the facilities of some of the largest carriers in the world. The signpost of every new railway station is a grain elevator or group of them. In recent years we have seen the phenomenal development of the Canadian Northern, the Mackenzie and Mann system, itself now almost a transcontinental system. Within the next five years a third transcontinental line, the Grand Trunk Pacific, will have been completed, which will materially widen the narrow strip of settlement by opening up a parallel zone of wild country on the north. Surveys for new branch lines are extending in every direction from the main systems. The transportation problem becomes greater. Canada is a country of distances. Her geography necessitates the development of her transportation routes along east and west lines. The fact of having a complete railway system across the continent renders it practicable to operate a line of carriers on the ocean at either end, as the C. P. R. have done in their Atlantic and Pacific lines of steamships. These railways with their ever-growing branches are very fully occupied in transporting the wheat from the great West to the ports on the Pacific, to the head of the Great Lakes or to the port of Montreal.

The period of development of the western prairies has also seen the improvements to navigation in the great St. Lawrence route. About ten years ago the Soulanges Canal, one of the artificial links in this immense chain of navigation, was completed and stands as a masterpiece of 15-foot canal construction. The never-ceasing procession of freight boats passing day and night in navigation season through the magnificent locks on the St. Mary River at Sault Ste. Marie represents the largest tonnage passing through any canal in existence. The River St. Lawrence, navigated by ocean vessels to the port of Montreal, 1,000 miles inland, has been improved so that there is a lighted and buoyed channel at least 450 feet wide, with a minimum depth of 30 feet at extreme low water. Three years ago a 35-foot channel was commenced by the Department of Marine and Fisheries from Montreal to the sea.

During the same period of western progression the carrying capacity of the railways to compete in some measure with the waterways has increased tremendously, necessitating heavier rails, bridges and rolling stock. The increased traffic has compelled the railway companies to drive two tunnels under the water route, one at Sarnia and the other at Detroit, the former having been operated electrically since the summer of 1908. The historic Victoria tubular bridge has been rebuilt into a modern steel through bridge, and the well-known Niagara Suspension has given place to a magnificent steel arch. All over the country the bridges have been rebuilt, the wooden ones being replaced by steel, and the lighter steel structures by heavier ones. Many interesting and important examples of the bridge-builder's art of every type have been erected throughout the Dominion.

Naturally adequate terminal facilities became necessary and as a result we see the immense elevators at Port Arthur and Fort William and at other points on the Great Lakes. The port of Montreal, which at present can be used for navigation purposes only seven months of the year through adverse climatic conditions, has developed until it stands to-day, according to the statement of the president of the Board of Harbor Commissioners of Montreal, third in handling capacity per month of all British ports.

While the West has been developing and expanding, the population of the East has grown with remarkable strides. Of the Ontario peninsula this is particularly true, the inhabitants having settled down to highly developed agriculture and fruit growing. Villages and towns are thriving everywhere. The cities have grown with great rapidity, due in a great measure to the evolution of electric traction. Twenty years ago the bob-tailed horse-car running on a single track was a not unfamiliar sight in our cities. To-day sixty-foot electric cars on a two-minute schedule are incapable of handling the passenger traffic in the cities, the streets are congested with traffic, and elevated and underground lines are talked of. Montreal boasts a population of half a million and Toronto 400,000.

The application of electricity to modern needs has played a most important part in the upbuilding of the cities and in manufacturing. In older Ontario electric lines join many of the towns and villages together and bring the city markets within easy reach. The cheap production of electric current has meant that practically all the waterfalls in the inhabited districts have been utilized, and it may be said that every community of importance in the Dominion has its own electric light even at the comparatively greater expense of steam production. Coal occurs in Canada only in the extreme East and in the Rockies, leaving the great middle distance to depend on fuel transported great distances or on water-power.

The most important hydro-electric developments of Canada are of course at Niagara, where it is estimated 5,000,000 continuous electrical horse-power can be produced. Of this about one-tenth will be utilized when the stations now running are fully equipped. Four stations on the Canadian side can produce about 450,000 electrical horse-power. Of this quantity the portion now being taken up by the Ontario Government as distributors, acting as the Ontario Hydro-Electric Commission, will be transmitted at 110,000 volts over the whole of the Ontario peninsula distances up to two hundred miles. The construction of these high-voltage lines is now proceeding and is near completion. Already Niagara power operates the electric street cars at Toronto, 80 miles distant.

Throughout the populated parts of the country, excepting perhaps in the extreme east where coal abounds, there are hydro-electric developments. Near Vancouver the mountain streams are harnessed. At Nelson the Kootenay River furnishes 20,000 horse-power for the mining of the district. Outside of Winnipeg the Winnipeg River provides over 20,000 horse-power for the city. At Sault Ste. Marie about 25,000 horse-power is used, chiefly for industrial works. The city of Montreal uses for light, heat and power from 30,000 to 53,000 horse-power developed at Lachine, Chambly and Shawinigan. Near the city of Ottawa about 35,000 horse-power is developed for civic use and for manufacturing. In addition to these there are a great many smaller plants in operation and under construction.

The mining interests have also been of importance in developing the country. The coal mines of Nova Scotia, and of the Rocky Mountains, as well as the lignite of Alberta must be mentioned. The gold of British Columbia and the Yukon likewise had its effect. The silver fields of Cobalt and the nickel deposits of Sudbury are known the world over.

In education what do we find? Thirty years ago McGill University had less than fifty graduates in engineering as a result of a course established twenty-five years previously. At that time the Toike Oikes had not begun to exist. Now McGill has practically a thousand graduates in applied science. Less than thirty years ago the first graduate in engineering at Toronto left the college halls. Now they leave by the hundred each year and the University of Toronto claims over a thousand engineering graduates. From the Royal Military College at Kingston each year about thirty young men enter practical life with a training in civil and military courses. The universities of the other provinces also have engineering faculties, and the Canadian graduates in engineering now number considerably over two thousand.

The engineering work of the future in Canada is great. Development along present lines of the art means much municipal work, power development and transportation. Before many years Canada will have a number of very large cities. Montreal, Toronto, Port Arthur, Winnipeg, Edmonton, Vancouver and Prince Rupert will be very important centres of population and distribution, presenting all the problems in water supply, sewage disposal, passenger and freight handling, and civic work. In addition to these there will be an immense number of smaller centres. Civilization will spread gradually northward. The

Peace River country will be thrown open to settlers at a very early period. The untold wealth of the Rockies will be available. The water-powers adjacent to the new settlements will all be utilized. The older part of Ontario will become a manufacturing district by the use of the white coal from Niagara and the Ottawa. The important rapids on the St. Lawrence will be developed for power and manufacturing purposes. The practically unknown district of northern Quebec with its mineral and timber wealth and unlimited water-powers only awaits the arrival of men and money. The railways will increase their branches everywhere. A new route will be created to Europe by joining the Winnipeg district with Hudson Bay—indeed, part of the money for the construction was voted at the present session of Parliament. The waterways will be materially improved. Deeper river and lake navigation will be provided between Montreal and Port Arthur. The Georgian Bay Canal, being the canalization of natural rivers and lakes along the Ottawa from Montreal to Georgian Bay, will surely be constructed in the near future. The railways will be operated largely by electricity instead of by steam. The ocean navigation to Montreal will be in use the whole year round by the aid of ice breakers operating between Quebec and the Canadian metropolis. All this means highly developed terminal facilities, and a quantity of rolling stock and machinery that is difficult to comprehend.

What of the future along lines not yet fully developed? It does not require any great flights of fancy to locate regular lines of airships of some type. The monorail railway is undoubtedly past the experimental stage. The future is more likely to be marked by development and improvement rather than by fundamental invention. Someone has said that the only thing man has ever invented is the wheel. Every other mechanical element he has used he has copied in some form or other from nature. He is an imitator and improver. In the latter years he is developing himself in that way. He may shortly discover that his electric wires are quite unnecessary, and that he makes his machines too complicated. He already knows they are extremely wasteful, that he obtains in his steam plants, for instance, only about 5 per cent. of the heat value of the coal he burns and wastes the other 95 per cent. New sources of power may be discovered. In thirty years hence the people may respect our limited scientific knowledge as little as we do that of our forefathers of fifty years ago. Time only will tell.

There is one other phase of the subject of engineering that I have not referred to. We have spoken in a general way of what the engineer has done and may yet accomplish. What he has not succeeded in doing is well illustrated by a story told to a university class in engineering economics by their honorary lecturer, who by the way is the first Toronto graduate in mechanical engineering. Certain Simians having a little more brains than their fellows used sticks with which to knock down their cocoanuts. They were the first engineers. Another Simian having still more grey matter congratulated them on their ability to select suitable sticks. Impelled by the flattery they went for more sticks, leaving him to knock down the nuts. He was the first financier. We have continued to gather the sticks, leaving the financiers to carry on their work. Maybe we shall yet learn enough to knock down the nuts for ourselves. Time will tell.

COST OF SEWER, MUSKOKA, ONT.

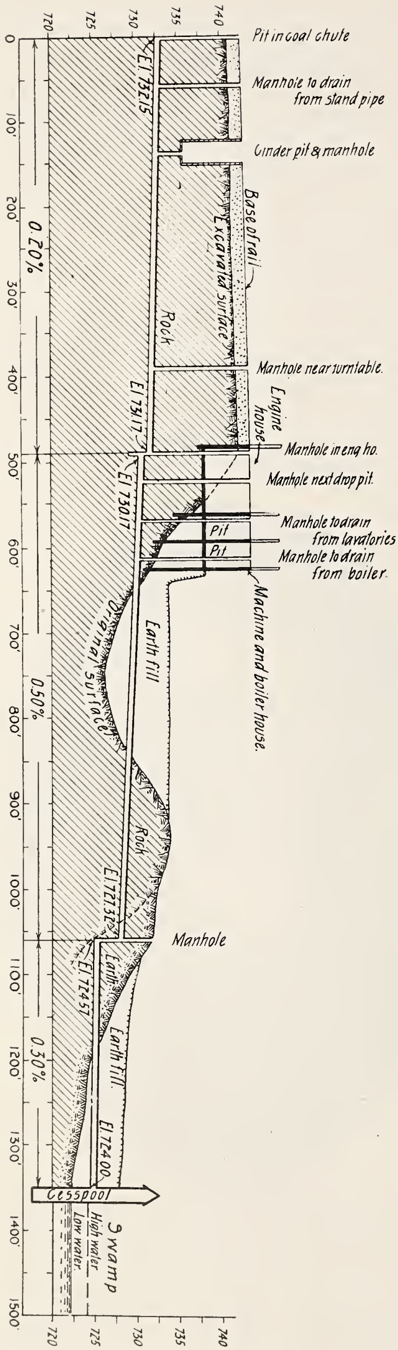
E. A. JAMES, B.A.Sc., A.M.C.Soc.C.E.

In September, 1908, the Canadian Pacific Railway opened their Toronto-Sudbury line. This line, two hundred and sixty miles long, runs from Toronto in a northly direction, leaving the Owen Sound branch at Bolton Junction, it passes to the west side of Lake Simcoe and crosses the G.T.R. Collingwood branch on the level at Utopia; the Penetang branch on the level near Coldwell Junction and the Midland branch on the level east of Coldwater. The line continues north, west of Muskoka Lakes, crossing over-head the G.T.R. (Canada Atlantic Division) near Parry Sound, and joining the main line of the C.P.R. at Romford Junction, a station seven miles west of Sudbury.

At Muskoka, one hundred and thirty-one miles north of Toronto, is situated the only division point on this line. At present it consists of a railway division yard, a small village of a dozen houses, railway station, round-house, machine shop, coal chute, etc., and a railway-owned-and-operated electric light plant and waterworks system.

In 1907 this district was uninhabited forest and when the new townsite was laid out under Mr. F. S. Darling, M. Can. Soc. C.E. Division Engineer, in charge of construction, the first work to follow the grading was the construction of a sewer.

E. A. James, B.A Sc., A.M.C., Soc. C.E.
Managing Editor, Canadian Engineer.



Surveys showed that the most suitable sewer to build would average ten feet deep through some seven hundred feet of Laurentian granite.

The work of digging the sewer was ordered to go ahead in the middle of July, 1907, and as the erection of necessary buildings for the yards could not be proceeded with until the sewer was completed, because of the blasting, the work was opened up in four places at once and four gangs kept busy until the work was nearly completed.

Continued dry weather made it possible to work to grade at the upper end of the sewer before the lower end was open so that work was commenced simultaneously at stations 0, 6, 8+50 and 11+50 at the same time.

The material from station 8+50 to 11+50 was wasted between stations 11+50 and 15+50, and from station 8+50 to 7, thus making this haul very short but the material from station 0 to station 6 had to be hauled about 1,500 feet, i.e., to the south end of the yards.

This material was broken by dynamite in the trench, mucked into skips and hoisted by horse-derricks upon horse-cars which ran on 30-pound rails.

The profile will show fairly well that there was about 550 feet of sewer 9 feet deep in granite rock and 350 feet about averaging 4 feet deep with a stripping of 2 feet of earth.

A close measurement of the work gave the following quantities :

Common excavation	950 cu. yds.
Loose rock	30 cu. yds.
Solid rock	1,850 cu. yds.

From the following calculations the common excavation and loose rock are eliminated as the cost of that work was kept separate.

The complete cost for 1,850 cubic yards of solid rock was as follows:

Superintending—			Per cu. yd.
Walking boss, at 60c per hour	$222.45	or	12.0c
Clerk and timekeeper, at 37½c per hour	158.60	or	8.5c
Foreman, at 45c per hour	608.15	or	32.8c
Total for superintending per cu. yd.			53.3c

Labor—Mucking, loading, hauling and dumping—

Laborers, at 20c per hour	$2,877.00	or	$1.555
Teamsters, at 21c per hour	499.70	or	.270
Teams, at 40c per hour	1,010.60	or	.545
Cars, at 5c per hour	117.00	or	.063
Carts, at 5c per hour	65.50	or	.035
Derricks and power, at 15c per hour	175.50	or	.095
Handy men, at 27½c per hour	125.15	or	.067
Total for labor per cu. yd.			$2.630

Drilling rock—

Foot drilling, at 30c per ft.	$1,245.00	or	0.673
Sharpening drills, at 27½c per hour	250.80	or	.135
Nippers, at 17½c per hour	382.20	or	.206
Coal, at $10 per ton	29.00	or	.157
For drilling per cu. yd.			$1.171

Explosives—

Electric fuses	$ 95.95
Caps and fuses	23.20
Batteries, rent	38.00
60% dynamite, at $10 per box	1,020.00
Or 0.636 per cubic yard.	$1,117.15

Making a total of $4.97 per cubic yard.

To this must be added an amount for the depreciation of plant, in this case $930. This included broken and wasted material and drill steel sharpened away.

This was equivalent to 50 cents per cubic yard and made a grand total of $5.47 per cubic yard. When it is remembered that it was rock work where the wear and tear upon plant was great this amount is not unreasonable.

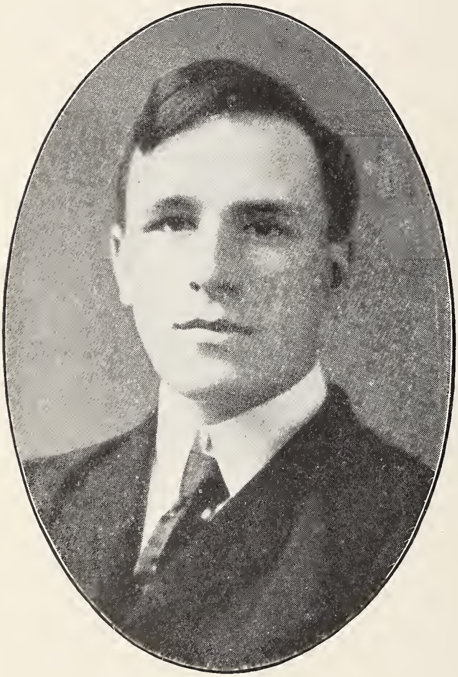
This price, i.e., $5.47 per cubic yard for solid rock, is high, but the trench was for 18-inch pipe; it was not wise to use large shots and the amount of drilling, i.e., one foot for 4½ cubic yards, was excessive. The price is not high for trench work in rock.

SAVING WASTE IN MANUFACTURING—A FIELD OF WORK IN WHICH THE TECHNICAL GRADUATE MIGHT WELL LOOK FOR A FUTURE.

J. C. ARMER, B.A.Sc.
Editor of the Canadian Manufacturer.

The technical graduate when seeking a job usually adopts the line of least resistance. Upon graduating few of us can afford to twirl our thumbs until our chosen job turns up. We usually are inclined to take the first good position that we can get. Circumstances usually have more to do with the character of our first job than our own plans and aspirations; and our first job has more to do with our second job than any other influence.

This is why we see so many technical graduates in certain lines of industrial life and so few in certain others. It is to the advantage of the technical graduate to have as many fields of industrial life open to him as possible — to have many lines of little resistance and few of great resistance.



J. C. Armer, B. A.Sc.,
Editor, "Canadian Manufacturer."

The Technical Graduate and the Manufacturing Industry—There will be in the future a closer bond of union than has been in the past.

The manufacturing industry in Canada (except what might be termed the purely engineering part) has been, for the most part, behind a closed door as far as the technical graduate is concerned. There is more than one reason for this; and probably every man one might consult on either side of the door would give a different reason, and most of these reasons might be correct. Being a technical graduate myself, and also having been brought into close touch with the manufacturing industry during the past six or seven years in a capacity which led me to study this very question somewhat, I realize a few of the conditions that prevent the door opening wider. Of course everything centres more or less around the fact that neither side fully realizes the possibilities of the other. That is the root of the evil.

I believe that the co-operative engineering course, that has been established at the University of Cincinnati, in which the student spends alternate weeks in the college and in different factories and shops in the city, is a part of the solution of this problem. The Faculty of Applied Science, I think, will come to it sooner or later. I know "the powers that be" are watching the experiment in Cincinnati with very keen interest.

In this connection the Executive of the Engineering Society are to be congratulated upon the idea which they carried out at their annual dinner in January; but it is to be deplored that the Board of Governors at the same time let slip such an excellent opportunity of establishing a better understanding by the manufacturers of the work the Faculty of Applied Science is doing through the new mechanical laboratory.

That there is a broad field of work in the manufacturing industry for the technical graduate need not be doubted. A few manufacturers in Canada are realizing it, and are employing technically trained men in positions heretofore held only by men who had spent the better part of their life at the work. The object of this article is not, however, to discuss this subject in general, but to bring to the reader's attention one line of work in the manufacturing industry for which a technical graduate—a student—a man who is trained to bring together cause and effect—is eminently fitted.

The "Saving of Waste in Manufacturing" is a field of work eminently fitted for the technical graduate.

This line of work is the "Saving of Waste." Not a very high sounding title, is it? "Quite beneath the aspirations of an ambitious technical man," some may exclaim; "he wants to construct —to build—not to save;" but before the reader jumps to a hasty conclusion, let him study the trend of modern industry—let him put his fingers on the pulse of modern manufacturing—and he will realize that the "Saving of Waste" is to be the most absorbing science on this continent at no very distant date.

Every one is more or less familiar with the remarkable strides which have been made of late years in the saving of waste in materials, but very few realize the waste which is bound up in the human element — the waste due to the inefficiency of workers. The technical student puts in most of his time studying materials, so that he can classify them, select them to advantage and get the greatest efficiency from them; and practically no time is given to the study of human nature—we have no data collected, no formulas with which to work; yet the real saving of waste in manufacturing has to do more largely with the human element than with the material or the machine.

Evidence of the possibilities there are of increasing the efficiency of workmen in the manufacturing industry.

At one time I operated a planer beside a red-headed Irishman in a certain railway machine shop. This Irishman was running a big slotter. Very many of his antics were very interesting and amusing, but the one that interested me most was his unfailing practice of first removing his overalls, and then stopping his machine, from fifteen to twenty minutes before time. That fifteen or twenty minutes he spent either huddled over his work—to give the foreman the impression that he was adjusting it—or else dodging around his machine to keep out of sight altogether. I wager he did more work in that time than in any other hour and a half. To my queries as to why he shut off his machine so much before time, he would answer: "Well, by the time you have worked as long in the shop as I have, you too will want to get out of as much work as you can." To take off overalls and otherwise prepare for a hasty exit when the whistle blew was natural, although possibly not laudable; but to work extra hard on his employer's time that he might not do the work for which he was paid, even when that work consisted of sitting on a box watching his machine cut the metal, is an exhibit of what the human element may mean in shop inefficiency.

Mr. F. W. Taylor, the author of that world-known paper, "The Art of Cutting Metals," presented to the American Society of Mechanical Engineers as a presidential address some few years ago, who has given more than twenty-five years to the scientific study of efficiency, says of the average workman's potential efficiency:

> "That the first-class man can do in most cases from two to four times as much as is done on the average is known to but few and is fully realized by those only who have made a thorough and scientific study of the possibilities of men. * * * It must be distinctly understood that in referring to possibilities, the writer does not mean what a first-class man can do on a spurt or when over-exerting himself, but what a good man can keep up for a long term of years without injury to his health, and become happier and thrive under."

The inefficiencies in the conduct of workmen which Mr. Taylor, and others such as Mr. Harrington Emerson, have found in a number of places are surprising and most significant. In the rough labor employed in the Bethlehem Steel Company's yards Mr. Taylor found an efficiency of only 28 per cent. Mr. Harrington Emerson determined an efficiency of only 18 per cent. in a gang of laborers excavating a foundation. He has found that the average railway repair shop shows an efficiency of only 50 per cent. He says that in the United States the total amount of preventable material and labor wastes and losses in railroad operation and maintenance approximates $300,000,000 annually. Harrington Emerson also says in one of his writings:

> "To the efficiency of a process or in the use of a material there is a clearly ascertainable maximum, and when it is exceeded the material gives way, as in the Quebec bridge; but to the efficiency of an individual there is no predeterminable limitation. In the passion for modern scientific accuracy much has been done to solve the lesser problem of efficiency in process or material, but the larger problem of individual efficiency has been almost wholly ignored."

In the face of this, and much more that a little investigation shows the student, does not this field of endeavor, "The Saving of Waste in Manufacturing," stand on as high a level as any other field open to technically trained men, and should not this practically untouched field in Canada appeal very strongly to a number of undergraduates and graduates of the Faculty of Applied Science!

What a few manufacturers in Canada are now doing in increasing the efficiency of their factories by the elimination of waste.

In Canada manufacturers are beginning to realize that immense amounts of money could be saved in materials and labor in their factories and plants; and efforts are being made in some places to effect these savings—the amount of the success depending upon the amount of good, hard study and good common sense put into the effort. I know of a stock room in a Toronto factory in which the manager increased the working efficiency 50 per cent. by a judicious handling of human nature, which, however, is a part of a well founded plan which extends over the entire factory. The manager had no data as to the increase of efficiency over the entire plant, but from figures available one might judge it would be 25 per cent.

The manager of a certain Toronto factory (the Canadian factory of the National Cash Register Co.) owing to a certain exigency was required to decrease the operating expenses of his factory by $12,000 per year, without interfering in any way with the quality of the product or the broad principles upon which the factory is operated. This factory manager was already doing what more than 75 per cent. of managers do in keeping down costs in the factory; and he did not think that he could cut out more waste to the tune of $12,000 per year. However, he called together his heads of departments, including purchasing agent, engineer and foremen, and put the problem straight to them. As a result of co-operation of all hands, this manager now has under way schemes which will save more than the $12,000 per year. This is an indication of what is possible in the saving of waste even when there appears to be no waste.

I might give other instances such as this; and they would all show the field there is for such work as this in Canada, and what openings there will be for the man who has made a thorough study of systems, organizations and human nature—theory and practice—the man who can go to the manufacturer for a job and in reply to the query, "What can you do?" say, "Well, I can increase the efficiency of your plant by 5 per cent. at least and possibly by 40 per cent."—of course in not quite such a bald manner. An answer such as that would certainly have more effect upon a manufacturer, one way or another, than an answer such as this: "Well, I can operate a planer, do some work on a lathe, and I think I understand Hirn's Analysis"—not meaning any disrespect to Hirn's Analysis.

What the technical graduate may expect in the way of remuneration in this field.

As to salary—the efficiency engineer in the United States who has accomplished things does not have to wear last year's hat, unless he wants to. From the nature of the work done it stands to reason that good salaries can be demanded. For instance, if in a factory employing 200 men at an average of $2.50 per day the individual efficiency were increased by 5 per cent., the saving in one year would be:

$$200 \times \$2.50 \times 300 \text{ days} \times \frac{5}{100} = \$9{,}000^*$$

or if the efficiency were increased 40 per cent., the saving in one year would be:

$$200 \times \$2.50 \times 300 \text{ days} \times \frac{40}{100} = \$72{,}000^*$$

The man who accomplished this could of course collect from it a salary that would look fairly large to the average engineer.

This field of work contains its share of necessary preparation, hard work, drudging, keen grasping of causes and effects, close study of present methods, a keen study any analysis of human nature, a continual collecting of data, etc., all this based upon a good sound technical training at college.

As to what the Faculty of Applied Science might do towards preparing a man for such a career, much might be said, but at the present moment one feels that it is bad form to suggest further burdens for the Faculty of Applied Science unless at the same time he comes prepared to pry open the treasure chest guarded by the governing powers, in which there may be a treasure and yet there may not.

---

* This method of figuring the saving is not correct, but the results are near enough for illustrating the point.

THE ACTION OF FROST ON HYDRAULIC CEMENTS—CONCRETING DURING FREEZING WEATHER.

ALFRED E. UREN, B.A.Sc.
Editor Canadian Cement and Concrete Review

In Canada and the Northern American States, where the effect of frost during the winter season is a more serious question than it is in many European countries, numerous experiments and investigations have been made to determine the effect of freezing temperatures upon hydraulic cements. The writer has endeavored to outline in this article some of the more important investigations made by various authorities along this line, as well as to call attention to the more common methods employed in practice of mixing and placing concrete during low temperatures.

Alfred E. Uren, B.A.Sc.

While the conclusions of different experimenters are not in perfect accord, from practical experience as well as from laboratory investigations, it is now generally accepted that the ultimate effect of freezing of Portland cement concrete is to produce only a surface injury. While experiments have proven that the setting and hardening of Portland cement concrete is retarded by freezing, and the strength at short periods lowered, still the ultimate strength appears to be but slightly, if at all, affected. Mr. Sanford E. Thompson, consulting engineer, is authority for the statement that neither in practise nor research has he ever discovered a case where Portland cement concrete or mortar, laid with proper care, has suffered more than surface disintegration from the action of frost.

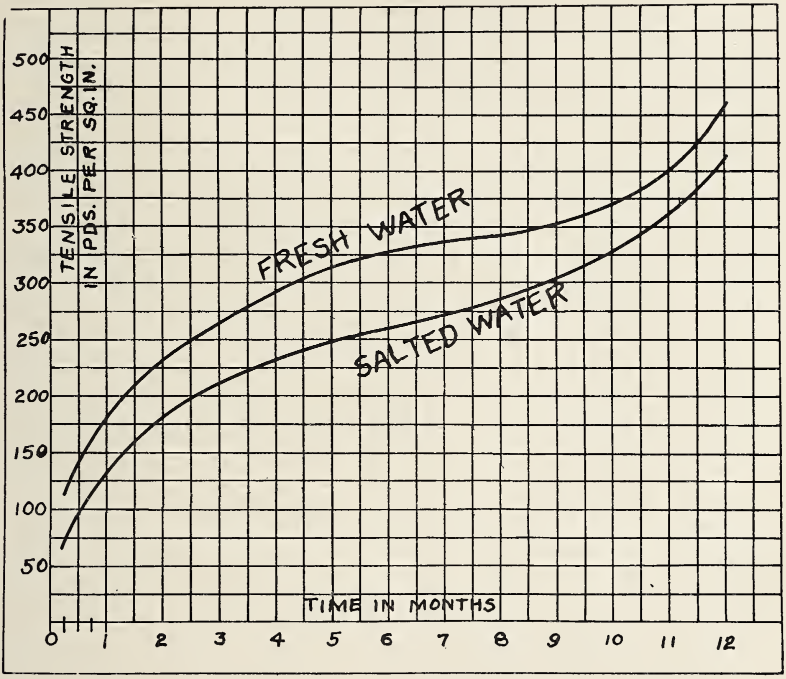
While authorities on the subject of concrete, in general, agree that concrete work should be avoided as far as possible during frosty weather, as it is much more difficult to mix satisfactorily and to place materials under these conditions, still if circumstances warrant this added expense, with proper precaution and careful inspection, mass concrete may be laid at almost any temperature. The proper precautions necessary to insure satisfactory results for work laid in freezing weather depend upon the class of work, heavy mass concrete not requiring the same care and protection as light reinforced construction. The subject, in so far as light work is concerned, is summed up in the words of Mr. W. J. Francis, consulting engineer, Montreal : (Paper read before the Canadian Cement and Concrete Association March, 1909.) "Do not erect light building work in reinforced concrete during freezing weather. If you are compelled to do so, be careful. It can be done but it means money and eternal vigilance."

A word of caution against the growing disregard of, and apparent indifference to, the importance of properly placing and protecting concrete work in freezing weather is not out of place. The practise of mixing, placing and caring for concrete work during winter weather in the same manner as in warm weather is, of course, to be condemned. The satisfactory results usually obtained during the winter months with Portland cement concrete serve as an incentive for increased activity and encouragement for carrying on concrete work under unfavorable weather conditions.

It is generally understood that concrete, frozen before the action of hardening has started, is not apt to be injured, if upon thawing, it is not again frozen until it has had a chance to harden sufficiently to withstand the action of subsequent freezing. The alternate freezing and thawing, which allow the intermittent action of hardening, are the conditions to be avoided. In laying concrete the surface freezes unless measures are taken to prevent it. It is well known that a thin crust, about one-sixteenth of an inch in thickness, is apt to scale off from granolithic or concrete pavements which have frozen before hardening. This leaves a rough instead of a trowled wearing surface. The effect upon concrete walls is sometimes similar.

As regards natural cements, they are particularly susceptible to serious injury from frost, especially by alternate freezing and thawing. Certain cases have been sighted where natural cement mortar has been laid in freezing weather with no serious results; there are, however, numerous examples where complete failure has been brought about. Mr. Sylvanis Thompson (see Concrete, Plain and Reinforced) has observed, that after several years, natural cement mortar was but slightly better than sand and gravel. These results were observed by him in the case of natural cement mortar laid during the comparatively warm winter of North Carolina, on days when the temperature was considerably above freezing at the time of laying, and also in the cold climate of Maine where the mortar froze as it left the trowel, without thawing before the spring season. Settlement of masonry when thawing is often a serious characteristic of natural cement. Occasionally tests are recorded in which natural cement mortars have after a time, attained full strength, in cases where they have been subjected to a uniformly cold temperature and then suddenly thawed. However, in view of the fact that there is some doubt on the subject, the investigations made are sufficient to warrant the use of a true Portland cement when frost is likely to occur during erection work, or before the mortar has thoroughly dried. Natural cements are but little used in Canada at the present time for construction work, nevertheless it is of interest to make these comparisons between the action of Natural and Portland cements.

Several methods are employed in practice to overcome effects produced by low temperatures. The following are those most commonly employed: (1) The addition of a chemical or chemicals that lower the freezing point of the water. (2) The application of heat to the aggregates. (3) Protection of work, by enclosure, etc. In the first instance, common salt (sodium chloride) is commonly used. Calcium chloride is sometimes used as experiments indicate that if used in quantities not exceeding 2 per cent. of the weight of the cement, it is an effective agent for lowering the freezing point of concrete. It should, however, be used with caution, since a larger quantity than this is likely to so hasten the set as to make the concrete difficult to handle. Other materials, such as alcohol, sugar and glycerine, have been employed in an experimental way. It has been found, however, that they have a tendency to lower the strength of the mortar. Specially prepared liquids and patented compounds have been placed on the market for the purpose of lowering the freezing point, in some instances with considerable success. These are usually dissolved in the water used for mixing. Salt is claimed by some to be detrimental to reinforced concrete, claiming that salt and air corrode steel and that even where steel is not present,



concrete is likely to become somewhat porous. These advocate mechanical means entirely where both moisture and heat should be provided.

As regards the percentage of salt to be added, authorities differ slightly. One method is to add to the water, one per cent. by weight of salt, for every degree Fahrenheit below the freezing point. One authority gives 8 pounds of salt per barrel of cement as sufficient, even in the coldest weather. Others recommend 1.06 pounds per cubic foot of cement. Ten pounds to every barrel of water used, is recommended by one authority.

An original method employed by some consists of adding sufficient salt to the water to give a 12 per cent. solution. A potato has a specific gravity of about 1.08. A 12 per cent. solution of salt and water has a specific gravity of 1.082, a solution which will float a potato. This method is sometimes employed in gauging the density of the salt solution. A 9 per cent. solution by weight of salt to water, was used in the construction of the New York Subway in 1903. On the Wachusett Dam, during the winter of 1902, four pounds of salt were used to each barrel of cement. For a 1 to 3 mortar this corresponds to about 2 per cent. of the weight of the water. Mr. Sanford E. Thompson has adopted the arbitrary rule of two pounds of salt to each bag of cement, to be used when the temperature is expected to fall several degrees below freezing, and if experience shows that this is not quite sufficient to prevent the frost catching the surfaces, three pounds of salt per bag of cement are to be used instead.

The accompanying curves plotted from experiments made by Mr. Chas. S. Gowen, extending up to one year (Proceedings American Society for Testing Materials, 1903, p. 393) show the effect, at laboratory temperature, of 10 per cent. of salt on a 1:3 Portland cement mortar, also that of fresh water.

Perhaps the more preferable method and one commonly employed, consists in mixing warm sand and stone with the cement and water, in such a manner as to bring the temperature of the entire mixture to about 75 degrees Fahr., protecting it from the air during the early stages of the setting. The water may be also heated. In the erection of a building for the Foster-Armstrong Co., Ltd., of Rochester, N.Y., the water was heated to about 90 degrees Fahr., and salt added in a proportion of about 1.06 pounds per cubic foot of Portland cement. The method of heating the water consisted of passing live steam through perforated pipes in storage tanks, and the sand and gravel were heated in the storage bins by means of steam pipes and hot air pipes. As each part of the building was constructed it was housed in by a temporary structure of timber and canvas, the open sides being enclosed by canvas curtains. The space enclosed by this housing was heated by coke fires and braziers, and by means of steam pipes from a central boiler, live steam being discharged into the spaces between the housing and the concrete.

The temperature in the enclosed spaces was kept at about 80 degrees Fahr., below the floors, and about 40 degrees Fahr. in the spaces between the top of the floor and its board covering.

Mr. J. H. Chubb, Assistant Inspecting Engineer Universal Portland Cement Co., Chicago (Bulletin No. 56, January, 1909) states that "Salt should be used only in plain concrete work, as its effect on reinforcing metal has not been established. Even when salt is used it is important that the aggregates be free from lumps of frozen material, as it is impossible to properly mix such materials. Approximately one per cent. by weight of salt to the weight of the water is required for each degree Fahrenheit below freezing, but more than ten per cent. of salt should not be considered safe and this amount is not effective for temperatures lower than twenty-two degrees Fahrenheit. The best method of concreting in freezing weather is to heat the materials and to protect the work until it has obtained sufficient strength to withstand the action of frost. Either the water, sand and water, or sand, stone and water should be heated. The cement is usually not heated. Heating the materials accelerates the rate of hardening, lengthens the time before the material becomes cold enough to freeze, and in temperatures but little below freezing will insure the hardening of the concrete before it can be damaged by freezing. For heavy mass work, thick walls, abutments, etc., it is not necessary to heat the stone except in exceptionally cold weather, but sand and water should be heated. If the forms are tight and made of heavy material, it will only be necessary to protect the top of the work; this may be done by covering with a canvas and running steam under it, or by covering with boards or paper and applying a covering of straw or manure. If such work is protected from freezing for several days it is sufficient, unless it has to be loaded immediately, but thin walls, light foundations, etc., should be protected on all sides in the manner pointed out above. For reinforced work it is necessary to heat all the materials but the cement, and the concrete should be hot when placed in the forms, and where the work must be placed into service as soon as possible, the only safe practice is to keep the surrounding temperature well above the freezing point until the work has thoroughly hardened. Concrete increases in strength but very slowly in cold weather, and for this reason forms should be left on as long as possible, and care taken not to load a structure too soon. Just how old the work should be before removing the forms and subjecting it to its load cannot be stated, as this will depend entirely upon how fast the concrete hardens. Careful inspection of the structure is necessary before removing the forms and applying the load, and it must be remembered that frozen concrete, which upon thawing has but little strength, closely resembles thoroughly hardened concrete in appearance, and when broken frequently shows a fracture through the aggregate. All classes of concrete work, with the exception of walks and pavements, may be constructed in freezing weather, but to insure satisfactory results proper precautions are necessary, which will entail an additional expense, depending upon the class of construction and importance of the work."

Engineering News (Vol. XLIX, No. 12) contains an article by Geo. W. Lee, where a combined water, sand and stone heater was used successfully. It was erected at a cost of fifty dollars and weighed about twelve hundred pounds. Considerable concrete work on the construction of Hurdman's Bridge, Ottawa, was carried on when the temperature was as low as 12 degrees below zero. In this instance the materials were partly heated, and partially protected with canvas cover after being deposited. A first-class concrete was produced. Engineering News (Vol. XLIX, No. 19) contains a description of the construction of a concrete dam at Chaudiere Falls, Province of Quebec. It was found necessary to construct a portion of this work during the winter months when the temperature ranged all the way to 20 degrees below zero.

The action of frost on Portland cement mortar and neat cement has been extensively investigated in an experimental way. A series of interesting experiments by Ernest R. Matthews, Borough Engineer of Bridlington, England (Volume XXXV, proceedings of the American Society of Civil Engineers) give in detail the action of frost on cement and cement mortar, together with other experiments on these materials. These investigations were made for the purpose of ascertaining, among other things, the effect of frost, and alternate frosts and thaw, on the tensile strength of cement and cement mortar when mixed with cold or warm water, also the temperature below which it is detrimental to mix Portland cement concrete. The cement used was manufactured by Robson's Cement Company of Hull, England, and conformed to British standard tests. These investigations led to the following conclusions:

(1) That light frost occurring 24 hours after the cement has been gauged (3° of frost, or thereabouts), is detrimental to freshly mixed Portland cement, but only for a short time, and that at the end of 28 days it has quite regained its normal strength. If the frost occurs immediately after the cement has been gauged, the effect is more detrimental, and would appear to be permanent. A minimum quantity of water should be added in frosty weather.

(2) That heavy frost (17° of frost, or thereabouts) has a most injurious effect (permanent) upon freshly mixed cement (neat), and cement mortar.

(3) That a light frost (3° of frost, or thereabouts) does not affect cement or cement mortar if it has attained two days' set previous to the occurrence of the frost.

(4) That the detrimental effect of light frost upon cement mortar (3 to 1) occurs more immediately than upon neat cement,

but that cement mortar recovers from the ill effects of frost more rapidly than neat cement. At the end of 14 days it has quite recovered.

(5) It would appear that it is detrimental to concrete to mix it when the temperature is below 29.3° F. (2.7° of frost), that being the freezing point of cement and concrete.

An extensive series of experiments conducted by Mr. Thomas F. Richardson at the Wachusett Dam in Massachusetts, extending up to one year, were sufficient to conclude that Portland cement mortar is not permanently injured by freezing. These experiments were conducted in the middle of the winter. Two bags of Portland cement were thoroughly mixed together and all the briquettes were made from cement taken from these bags. These experiments were carried on while the masonry work on the dam in question was in progress. The briquettes that were tested were made each week and submitted to the same conditions as the masonry, the moulds being placed in the open air and not in water, immediately after filling. At the same time briquettes were made that were kept in the laboratory. Those out of doors were exposed to temperatures as low as 9 degrees above zero during the first 24 hours, and some to temperatures as low as 12 degrees below zero during the first week. Salt ranging in quantity from 4 to 16 pounds per barrel of cement was used in most of the experiments (the average being about 3 per cent. by weight of water). These experiments indicated that 8 pounds of salt per barrel of cement is sufficient even in the coldest weather, that 4 pounds is very nearly as good but that 16 pounds does not seem to give quite as good results. The following table, which gives the average results of these experiments, shows the effect of frost upon the tensile strength of a 1 to 3 mortar mixture:

Briquettes Kept.	No. of Briquettes	Tensile Strength, lbs. per square inch.				
		7 Days	28 Days	3 Months	6 Months	1 Year
Water in Laboratory....	20	268	304	359	370	401
Air in Laboratory......	20	298	352	364	392	517
Out doors, below freezing	80	139	238	344	435	627

Table showing the effect of frost on the tensile strength of a 1: 3 mortar mixture.

During 1901, interesting and valuable experiments were conducted at the Watertown Arsenal, U.S.A., to ascertain the effect of low temperatures upon the strength of cements and cement mortars, the results of which are given herewith. For a complete description and results of these experiments see "Tests of Metals," U.S.A., 1901, page 530, from which these results were taken. A part of these experiments consisted of placing groups of cubes in a cold storage warehouse, where some of them were subjected to a temperature of 39° F. and some to a temperature of 0° F. Those subjected to the lowest temperature were mixed and moulded in a temperature below freezing. All cubes were subjected to the tabulated temperature as soon after mixing as practicable, and before being tested were kept at a temperature of 70° F. for the number of days indicated. Herewith are tabulated some of the results on cubes composed of a 1:1 Portland cement mortar, gauged with 16% water for the group subjected to 0° F., and 12% water for the other group.

EXPERIMENTS CONDUCTED AT THE WATERTOWN ARSENAL TO DEMONSTRATE THE EFFECT OF LOW TEMPERATURE UPON THE STRENGTH OF CEMENTS AND CEMENT MORTARS. THE AVERAGE COMPRESSIVE STRENGTH OF FIVE CUBES IS GIVEN IN POUNDS PER SQ. IN.

Days at 0° F.	Days at 70° F.	Strength.	Days at 0° F.	Days at 70° F.	Strength.	Days at 39° F.	Days at 70° F.	Strength
5	1	287	5	7	846	15	0	1710
14	1	321	14	7	1000	31	0	1960
21	1	337	21	7	1010	60	0	2460
31	1	383	31	7	981	15	7	2710
60	1	416	60	7	981	31	7	2720
90	1	497	90	7	1010	60	7	3270

The results of practice and experiment with cements exposed to frost lead to the following conclusions:

1. Most natural cements are completely ruined by freezing.

2. Frost expands natural cement masonry and settlement results with the thawing.

3. The ultimate strength of Portland cement in mortar or concrete is but slightly, if at all, affected by freezing, although its setting and hardening is retarded and its strength at short periods lowered.

4. Heating materials hastens setting and retards the action of frost.

5. Salt lowers the freezing point of water and does not appear to affect the ultimate strength of the concrete or mortar, if added in quantities up to ten or twelve per cent. of the weight of the water.

6. A thin scale is apt to crack from the surface of concrete walks, walls, etc., if frozen before the cement has hardened.

7. Concrete work, if possible, should be avoided in freezing weather because of the difficulty and expense of attaining perfect results.

RECENT ADVANCES IN ELECTRICITY.

CLARENCE E. BOTHWELL
Associate Editor Canadian Electrical News

Ninety years ago electricity was defined in an American text book as that property in bodies in virtue of which, when rubbed they attracted substances and emitted fire, and even as late as fifty years ago this might have represented the popular knowledge and conception of things electric. The slow evolution which has transpired is not unnatural and in dealing with electrical science, history has but repeated itself. Throughout all ages the progress of any change destined to be of world-wide importance has always been notoriously retarded. The disconnected theorem of the scientist must first be given to an unheeding public. Perhaps a few generations later these same principles are embodied, through the genius of the inventor, in a device which constitutes a distinct advance in commercial progress. The next step is to secure the adoption of the invention by a sceptical industrial public. In this sphere radical departure from methods of accepted procedure always have met with deep-rooted opposition, and at the best only a modification of the device in hand is accepted. Once, however, the confidence of the industrial world is obtained the appliance of meritorious value makes rapid strides.

We find that the fundamental principles of electricity were exploited by eminent physicists years before they were turned to commercial account, and the invention of electric machines received but scant attention until many years after their preliminary investigation and actual commercial establishment. Twenty-five years ago incandescent lamps were an advertised feature of industrial exhibitions and were considered a freak rather than a factor in the country's development. The changes within the last decade have indeed been wonderful. Electricity and progress are interchangeable synonyms and the world recognizes that mostly all recent accelerations of modern business conditions are the achievement of the electrical engineer.

In the operation of industrial establishments, electrical power is forcing recognition as an important factor. Its entrance to this field is not of long standing. First, came its use in an auxiliary capacity for the operation of special or isolated machines and gradually upon its merits it superceded other forms of power for factory operation. To commend it were many striking qualities: Its absolute cleanliness; its adaptability to the closer speed regulation of modern high-grade machines; acceleration of output, which the perfection of the high-speed motors made possible; the economy of space afforded in the system of power distribution over other more mechanical methods; its cheapness, where water power is available, compared to other methods of operation.

To enumerate the every-day uses of electricity, all of which have had their place in the world's industrial progress would entail a needless repetition. To mention the myriads of opportunities for its application would be impossible. Wireless telegraphy with its more or less widespread use is but in its infancy. Marine electrical propulsion has been receiving serious attention and for some years has been quietly asserting itself as an art and an industry. The propulsion of ships was one of those greater power applications of electricity which were necessarily delayed pending the perfection of a means of generating large quantities of electrical power cheaply, but the recent advances in design, construction, and operation of the steam turbine and gas and petroleum engines has brought the successful consideration of this problem within sight. At this distance it would appear that electrical transmission of power offers the solution to the ideal slow-speed propeller and a reduction in weight and capacity of the boiler room through the economical operation of the prime mover.

The achievements of electricity in the realm of the newspaper are none the less noteworthy and give every promise of facilitating the movements of this important branch of the industrial field. In the printing shop, the introduction of proper driving motors and controlling devices may be looked for which will revolutionize the art of printing. A striking instance of progress may here be noted. Not long ago the London, England, "Evening News" was enabled to print verbatim a speech delivered by Lord Rosebery in Glasgow, and to have its edition on the streets in London before the speaker had left the hall in Glasgow. This wonderful feat was accomplished through the instrumentality of the electrophone—a specially constructed and extremely sensitive telephone, devised by an Italian scientist.

The growth in demand of electricity for power purposes has led to the adoption of larger generating units and as a consequence, in recent years the trend of manufacturers of electrical machinery has been to show a remarkable progress in the utilization of materials, and in their later machines they have managed to show a larger output in proportion to the quantity of materials used. The demand for larger units has thus been met and it has facilitated the distribution of power over a larger area and at higher pressures. The invention of the suspension type insulator has materially assisted in the design of high potential circuits and shortly we will see placed in operation the 110,000 volt line of the Ontario Hydro-Electric Power Commission, an engineering construction that in magnitude of projection will for some time remain in isolated grandeur.

One cannot but feel that this is the age of electricity and that Canada will have a large share in the gradual uplifting of the industrial efficiency of the world. When the existing power companies and companies of the future have taken full advantage of the magnificent water power resources of this country, the day should not be far distant when a closely woven network of electrical wires will furnish the smallest and the largest centres of this country of ours with all her power requirements for industrial, commercial and agricultural purposes.

The present day electrical engineer must be a broad man. First and foremost, he must be a Booster, a full-fledged member of the Boost Club. His motto shall be: "All together all the time for everything electrical."

The engineer must also be a business man. He must be a firm believer in advertising. Engineers take too readily for granted that the general public are familiar with all the advantages and developments of electrical power. As a rule the public are extremely ignorant in matters pertaining to electricity, with the exception, perhaps, of the electric railway problem.

Above all else the engineer should be an optimist—believe firmly that the demand for electrical power will grow rapidly; encourage a customer to instal a machine larger than his present day requirements; your load-factor may suffer, but do not lay too much stress on this; be big enough to drive through it. Later on, the chances are that this customer will add to his load and thus increase your power-factor. With a small motor connected in, he will over-load and troubles from short-circuiting may frequently be expected.

Lastly, to facilitate electrical progress, engineers must cooperate, not only in the collection of technical data but in the furthering of the general electrical interests. For instance, we should learn a lesson from the experiences of the Ontario Hydro-Electric Power Commission regarding the question of easements for power lines.

We cannot expect to obtain general improvement to the law with regard to easements for overhead lines until a strong case is made out, by the collection of data from all interested countries, showing the present disadvantages suffered. This example is one of many, but will serve to show the urgent necessity for co-operation amongst members of the electrical fraternity.

INDUSTRIAL EDUCATION.

K. A. MACKENZIE, B.A.Sc.

Managing Editor, Applied Science.

That Canada has at length awakened to the advantages and necessity of Technical Education can no longer be doubted. The speech of J. P. Murray, in the February "Applied Science," shows that our manufacturers have been and are giving the matter considerable thought. Technical Education may be roughly said to treat of the application of the principles of science and art to the agricultural, industrial and commercial interests of the country. Before going into the question it might be well to discuss briefly the history of education, keeping always in view that a school education must not only prepare a student for life but also to make a living.

The only education in book form which survived the Dark Ages was held by the monks. As years went by, they disseminated what learning they had to their successors and, in homeopathic doses, to the lay population. They appreciated that in book learning lay a power worth preserving. Other learning, the knowledge of crafts and practical knowledge was passed by word of mouth, precept and example from father to son; from master to apprentice; never gathering momentum because there was no literature to preserve and collate its mysteries. Thus it is that some of the practical industrial secrets of the ancients have been lost to the world for long ages.

K. A. Mackenzie, B.A.Sc.

In those early days began that mutual contempt between the practical, represented by the guilds, and the theoretical, represented by the monks. The latter dominated through the power of logic, from the accumulated philosophy of centuries, over the limited, self-centered and self-sufficient secrecy of the trades. The advantage then gained has made itself long felt and this monk-made education is still dominating our educational systems. It gave us the dead languages, mathematics and philosophy; but it barred from the schools and from the world their practical application.

This was the state of book learning at the time when technical schools were first established. The founders of these schools were in many cases hard-headed men of affairs with large faith in the schools they proposed and small idea of how to accomplish their purpose. These men expected these schools to turn out men skilled in trade; men who should become leaders of men. Since they were to be schools what more natural than that they should engage men from other schools—that is, colleges—to lead them, and what was more natural yet than that these same men should make these technical schools what they are, merely schools with technical leanings. The technical school product thus necessarily failed as practical workmen, but soon evolved into competent designers, engineers and leaders. This was quickly seen and they immediately disdained the very product which they were originally engaged to make. They began to change their schools into engineering schools, which change is at the present day nearly complete.

The graduates of the technical schools aroused the jealousy of the man educated in the shops. The shop trained man had manual dexterity and if he added native ingenuity and mechanical interest he succeeded. The school man had mechanical theory and trained method of reasoning and, if added to this he had a native ability to understand shop processes, he too succeeded; in time, ability being equal, out-distancing his competitor, but those who acquired the necessary dexterity did so only at an expense of time entirely out of proportion to the results gained.

The first attempt to provide skilled workmen having failed, manual training was hailed as the succor needed. Manual training has done all that its real projectors expected but nothing at all of what its later advocates claimed.

Now the trade school movement is having its boom. All over the country there is quite a movement in favor of trades for the younger generation. The barriers between the theoretical and the practical are breaking down. Soiled hands are no longer regarded as not creditable. The pendulum is now swinging the other way, recognizing the usefulness and dignity of the man who makes things. All men cannot be engineers and professional men. From the people, however, comes a demand that there shall be an opportunity for their sons to learn to work with their hands to the best advantage. From the manufacturer comes the demand for educated and resourceful workmen, from the country comes the cry for conservation of all of the raw materials, that of labor included.

The low efficiency of the workmen in various trades in Canada is becoming a cause of concern, not only to the employers and owners of industries but to the leaders of organized labor as well. The present day tendency for specialization has made it well nigh impossible for apprentices to get a good general knowledge of their trades such as in former years was quite possible.

It has been noted, however, that workmen coming to this country from Germany are better all round workers than the average man in the same occupations.

It would be interesting to note the reason of this. In Germany, all children are compelied to attend the ordinary culture schools till they reach the age of fourteen. In these general culture schools they receive also manual training exercises intended for general education. In the "continuation" schools, the instruction is by skilled mechanics and tradesmen. In them one may learn to be a bricklayer, a carpenter, a blacksmith, and so on, receiving a thorough two years' trade school training by experts in the trade.

This system could be easily incorporated into our Canadian educational system. We need similar vocational schools that we may prepare our young workmen to be more efficient workers, more skilful and less wasteful. For years the province has been spending money on general culture and higher technical education with no corresponding outlay for those, and they are the vast majority, who cannot attend school past their fourteenth or sixteenth year.

However, the system could be advanced still further. Hand in hand with our high school system, we need a further, more advanced class of vocational schools for students who have completed their general culture-high school course at the age of eighteen and wish to spend not over two years in becoming proficient in one of the more advanced trades. In these higher vocational schools could be taught occupations such as lithography, printing, machinist, and so on.

This vocational training would not interfere with the manual training which is now given in our high schools and which would be continued as general cultural education, to students in all courses, so that they may have trained eyes and hands, with a knowledge of the arts and crafts in general.

By this arrangement we have provided for the students who cannot go to school beyond the periods of primary and secondary education respectively, by giving them an opportunity in separate schools, to gain vocational training. At the same time we have kept the curricula of the primary and secondary schools free from vocational studies and can devote the time to the work that will best prepare for citizenship and for life in its broadest sense and also at the same time retain a section of our secondary schools for such preparatory studies as are needed for entrance to the university, and engineering colleges. Our engineering colleges should also provide courses more strictly along the lines of industrial management.

The greatest demand made on engineering schools thus far by students, their parents, and their employers, has been for technical specialists, and the need will always exist for graduates prepared to become chief chemists, head electricians, chief draughtsman and designers. But there is also a need for men so trained that they can be developed to fill positions in industrial management. Our industries are at the present suffering from the lack of such men as these—men who are not only thoroughly familiar with productive processes, but have broad human interests and are at the same time thorough business men.

Our captains of industry are recognizing the need of these men, which is a hopeful sign, as it has been proven time and again that any system of technical education is liable to failure unless it is preceded by an active demand from those whom it will benefit.

In the past so large a proportion of our technical graduates have found employment in the large electrical and engineering corporations, that the smaller industries of the country have not availed themselves of the services of technically trained men to any considerable extent. Yet the most wasteful power plants, the most inefficient manufacturing processes, the most uneconomical building arrangements and poorest organization methods are found in the smaller industries.

The young graduate, be he ever so good, and no matter what his course of study has been, will not of course be able to revolutionize matters shortly after his employment in such an industry. Yet he should be able to save his wages many times over, from the beginning, if he has been properly educated.

These men must be trained along three lines. They must be thoroughly grounded in engineering, they must have creative ability in applying good statistical, accounting and system methods to production; and, finally, they must know something about men, possessing some of the innate qualities of leadership, it being presumed it is only the picked men who reach this rung of the educational ladder.

Having mapped out in a slight way the ground of industrial education, the question naturally arises, what parts should the different interests assume in the movement.

The Dominion Government should be the source of information and a centre of dissemination on all questions of technical education to all parts of the country. The United States Department of Labor and the Commissioner of Education perform such an office.

The Dominion Government, which can subsidize a single industry—the steel industry—to the extent of $16,507,200 to develop the raw materials of our iron mines, and its infant industries, should surely be able to subsidize industrial educational to develop the raw material of our labor. A study of conditions in foreign countries shows that the system of vocational schools receives great assistance from municipalities, manufactures and labor organizations. As to the Province contributing liberally there can be no question.

Hon. A. G. MacKay, speaking on technical education before the Ontario Legislature, urged the province to unite with the municipalities in the establishment of craft or trade schools in the cities and towns to supplement the practical training of the workshop, and effect an arrangement as to the basis of their support among the province, the municipalities and the interested manufacturers. He also urged the establishment in large industrial centres of technical high schools, towards the support of which the municipalities should be empowered to contribute.

It was, the Liberal leader forcefully pointed out, no adequate apology for lethargic action on the part of the province to submit that the Dominion was going to "do something." The Dominion, he had no doubt, would do its part, but the Federal Government was careful to observe the limits of its jurisdiction. Education belonged exclusively to the province. The Federal Minister of Labor was sending out a commission for the purpose of gathering information. It was true that efficient and effective industrial education would enhance the trade and commerce of the Dominion, and to this end it was to be expected that cooperation would be extended. But the responsibility and the opportunity were with the province. He urged the Legislature to be up and doing.

In concluding his address he spoke as follows:

"Let us analyze our system of education. We are generous to the high school and collegiate student; we do not withhold our hand to the normal and model school pupil; we are liberal to the university scholar; we extend practical encouragement to those who are in attendance at the Agricultural College. All this is well. But what about the lad whom chill penury sends to the workshop at an early age? We don't spend a dollar on him.

"Let us be frank and honest with ourselves. Our educational system is poorly balanced. It is a matter of vital importance that this should be remedied. It touches not alone the industrial problem; in the larger sense it affects the ethical side. The State cannot afford to drop these boys. The need of the day is something for the child of the wage-working class.

"This is not a political matter. It is provincial. Neither the old Government nor the present Government have evolved any adequate solution of the problem which confronts us. We mean well enough, but we lack intelligent direction. It is high time to do something."

By all means one of the most important functions for the Dominion Government to take up is the question of **Research**. This could be done by the establishment of a National Research Bureau similar to the Watertown Arsenal, the Structural Material Laboratory at Pittsburg, Pa., and in connection with the different laboratories of the leading American Engineering colleges.

The executive of the Canadian Society of Civil Engineers are now pressing the Federal Government along these lines.

Tuition would be in no part the duty of the Research Bureau. It should be manned by the best men obtainable. Their work would consist in the investigation of our resources, whether occurring directly in nature or as by products in our industries. There are a thousand and one problems awaiting solution. The problem of electric treatment of iron ores, so ably handled by Dr. Haanel, is an example. Many sources of economic waste might easily be stopped and millions of dollars added to the national wealth. On this phase the example of Germany need only again be quoted to show its importance. The difference between success and failure, between partial success and wealth, often lies in the waste heap and the treatment of by-products.

Too much attention cannot be given to the research problem in our universities. In our Canadian engineering colleges we are sadly hampered by the lack of funds and equipment. The possibilities for good by direct results and the training of men capable to carry on further investigation are obvious. In Ontario to-day the problem of sewage disposal is ever pushing itself more into prominence, yet we have little or no definite knowledge as to local problems. It is true that the Ontario Government has established a laboratory in Toronto, but this is being treated more as a bacteriological station than for investigating the problems of sanitary engineering.

The example of the Sanitary Research Laboratory and Sewage Experimental Station of the Massachusetts Institute of Technology at Boston need only be quoted to show the possibilities and the immense advantages to be derived from such a station. In other lines, the work that the Agricultural College at Guelph does for the agricultural industry might be duplicated for the manufacturing industries.

The Faculty of Engineering is the only Faculty of the University of Toronto lacking research scholarships. This hinders the work greatly. The graduates are taking the matter up and promise soon to have a start made.

A movement should be started to keep before the manufacturers the possibilities of research. This might possibly result in a manufacturer or a group of manufacturers providing funds for the maintenance of a fellow whose time would be primarily employed with a particular line of research, but given in part to university work. This plan has worked successfully in the University of Kansas, being introduced by one of our Toronto graduates, Prof. R. Duncan. Its initiation here would give an immense and needed impetus to the work in the University of Toronto.

THE TECHNICAL WHO'S WHO.

PREFACE.

"Applied Science" does not hold itself editorially responsible for the opinions expressed in its papers by authors.

A canvasser has requested Mr. E. C. Easy, C.E.—that walking stress diagram of eminent engineering intellectuality—to join the new social club for technically trained men in Toronto, and desired to know whether the notable expert wished to be fyled away as an engineer, or a surveyor, or an architect; and if the first, what kind of one. There was the rub. Mr. Easy could not make the grade.

The great man was undeniably cross. He unloaded himself on poor, defenceless me. He does not usually employ strong language but he flung everything to the winds on this occasion. He smote his thigh.

"Crumbs!" said he, "Bread crumbs!" With that he blushed.

"Whither are we drifting?" querulously he demanded, his thought-corrugated visage astare at the ribs in the arched ceiling. "Where is our ancient and honorable profession off-getting-on-at? What would Stevenson have thought, what Smeaton said, not to mention James Watt and other foot-rule gentry—the old masters of rare technique who inveigled their pictures into history, as authorized for use in the public schools in Ontario." Mr. Easy shifted his chair and contrived a bow-knot out of his long legs. He was getting wound up.

"I would just like to have glimpsed the dago face of him had *Nonius Datus*, Esq., C.E. (A.D. 152),* the underpaid hydraulic engineer of the Third Legion, been button-holed. as to his *toga virilis*, by my friend the canvasser.

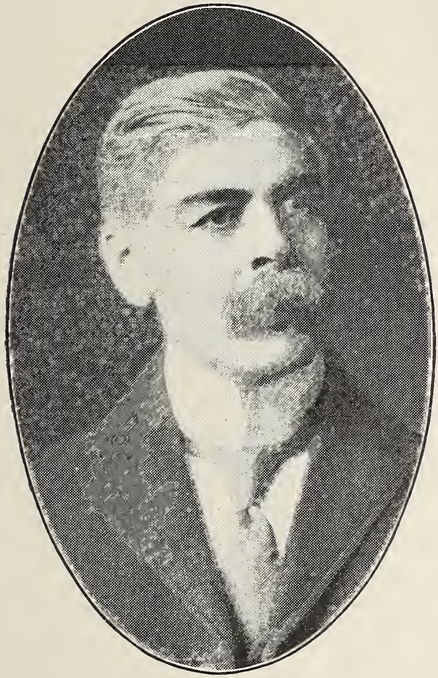
"He said he was a young engineer. He had a viz that looked as if a lot of field rivets had been skipped. But he was oily—slicker than the hair on a Petrolia frog. He was so smooth he wouldn't retain at 50 to 1, and that's agoing some, as they say in the Arithmetic. However, he didn't get mine in his bunch of classy tracing-cloth signatures. This new club is to consist of engineers, architects and surveyors. Do you take me? A dinky triangle of money-needing forces. Now, as proved by laboratory tests, I'd crave to enquire, where's the dividing line, the party wall. When they say engineer, do they mean engineer, or (perhaps it is shown plainer on a section), when is a hen?"

I kept still, perfectly quiet. Mr. Easy—that past master of scientific profundity—was not one to be argued with. Perfect, beatific stillness. The sound like a giraffe gargling was only a water pipe outside.

Mr. Easy resumed. "I s'pose that fat-head canvasser tried to see would I get rattled; must think I'm chief engineer at a mechanical toy factory—baby rattles a specialty. He is apt to be in the Burke's Peerage of Smart Alecks who would belay you to a street corner and cause you to miss a transfer while he contributed to your already over-flowing think-reservoir the balmy, uplifting hypothesis that hydraulic engineers trek in two brigades—those who work at it and those who drink it. The muzzle legislation should include the likes of him. Wouldn't his pronouncements add to the gayety of nations and merit a floral tribute of price; wouldn't the mover stand a good chance for the chairmanship—he'd be carried out unanimously. Never mind, don't worry, the golden orb will yet rise on a working day of 24 hours when he'll find his own level — also transit. Civil Engineers and impolite surveyors alike are often fain to. And often borrow them —also other articles of a field-work toilet."

---

* Dean Galbraith's Valedictory as President of the Canadian Society of Civil Engineers (1909) was evidently surging through a certain brain, which we will designate as "X"



C. M. Canniff, B.A.Sc.
(E. C. Easy, C.E.)

"Bug-house! I should so conjecture. Right up to the nth! He'll never turn out any John G. Pocketfiller, or J. Bluepoint Sturgeon, or Lord Skincoona. That's my one best comment. I fully expected him to volunteer that a sanitary engineer is one who may be crazy, but lacks the funds to board at a decent, comfortable Insane Asylum. Oh. Crumbs! Also that a Railway Engineer, if you get on to his curves, is different to all others, because he travels in a special train of thought. How would that hit the genial, sage, and strictly moral architect of a jerk-water stump-dodger? Without the aid of a lens one could discern the palpitating bulges made by pathetic, lost-chord, looney ideas of that character taking exercise in his forehead's back-yard."

"I expected him to tell me that Mining engineers are noted for doing a lot of low-down work, and being experts on the seamy side of life. What? No, that canvasser's got no surcharge of technical fill behind his back. He an engineer!

Crumbs! Crumbs! If he were my assistant for about a minute I'd kink his tape, I'd glue up his slide-rule."

"He'd not be suggesting any more that Roadway engineers should mend their ways; or that a Surveyor's best plan is to make both ends meet when he starts in to callous his elbows over the drawing-board; how would they, for instance, like to be told that surveyors don't work at all—simply are low comedians, playing problem plays at measure for measureable wages? Like as not one of his simpering inanities would be that all engineers, save the stationary fellows, are generally working themselves out of a job. I believe really that that chap could encase a square meal and dreamlessly go to 'bye-bye' after defining a civil engineer as one who made mountains out of mole-hills, and vice versa, each to each; likewise explaining how they were called civil, enjoying as they did a bowing acquaintance with other clans of engineering talent."

"Answer me. Why can a punk applied mechanic like that buy India ink at the same price I pay? Consider not a kid-gloved vernier twister at all—for even a common draughtsman who draws the line at $40 per—making black scratches on white paper—could tear off reams of lunatic specifications like that. Possibly have the decency to accord his face a flat-wash of carmine too. A licensed set square chauffeur doesn't amble forth in the stilly night and imagine himself formed into a scientific brain merger every time he feels chesty enough to buy celery and Roquefort after an evening's close figuring at the Star Theatre or the Gayety. He resembles our University—he's got some reasoning faculties."

"How would a surveyor like to be called a *'Poduk-asin Ashish-kie-ikank'* just because it's Ojibway for 'stick-in-the-mud.' That's the brand of insipid sop his crater would be liable to erupt. He'd be spending that grade of small change like a soused inmate of one of our saucy Canadian Dreadnoughts. It's enough to make a really truly and sincerely engineer hire an aerotaxi and drome away and dee."

There are engineers by profession and those who profess to be engineers. Both amateurs and professionals enter the engineering Marathon. As Peary remarked with that 'welcome-to-our-Polar-City-smile' of his: 'Many are Cooked but a few are frozen.' More probably Peary was considering a human being than cold storage meat. What yer know 'bout dat?"

Now, it is an interesting—to most a likeable—attribute of Mr. Easy, this eminent authority with a strangle-holt on technical wisdom—that one can rarely fathom whither his next thought is trending. In his public or private life one can say, like the girl with steel corsets who learned to run a compass—he has a certain inherent attraction in his surroundings.

"I'll bet a silver-plated protractor as big as a cart wheel," asserted he, "against a rusty pair of spavined dividers that that pin-head canvasser will suggest to the Chemical engineers a letter-heading along the line of the attached sublime sentiment:

'Little Johnnie's dead and gone,
'We'll never see him more;
'For what he took for H_2O
'Was H_2 SO_4.'

Dot is sense, vot it is, is it? Ach!

"How would an individual who ponders week in, week out, in terms of galls. per sec., or lbs. per sq. in., care to be told that a Mechanical engineer can be identified by the oil he puts in his salad dressing? Would getting caught in a belt like that be a relish? Oh, you kiddo! Would you subscribe to a Structural engineers' being one who approves a rotary mixer rather than every-day Radnor, or an occasional observation of Apollinaris, with its accustomed satellite. Details of the personal character of Electrical engineers, with him, would pass current for juicy. Isn't that joke ripe for its old age pension? Do Elevator engineers make a social pastime—a pay-as-you-enter relaxation—out of the gold cure? Woe's me! I imagine he considers the Architect's function is to take an engineer's plan and dot the i's and cross the t's, and put some curlimagigs on the capitals."

It was at the Engineers' Club that Mr. Easy had unbosomed himself to me as above. Two or three members had joined us in the interval. Then the power went off, the lights went out, and everybody made for the street. As I felt my way down stairs I could catch some drift of a hit-the-bull's-eye definition of an engineer: " a man" (as near as I could gather) "with a quality of brain to figure out beforehand that it's not necessary to turn a horse upside down to get on its collar."

Here a slip on a step, and a quick-fuse, muttered invocation to—sounded like "Happy Hooligan" or "Holy Hexigons." Then a match scratching....a little later, "but that canvasser.... light another match, light two, light a box....his advertisement would read....

" 'Bridges Designed Free.
If not Built
No Harm Done.' "

And next...."Sure! He was *maison du scratch*....them's Penetang French for 'bug-house.' "....Another slip on the stair.... a determined, seismographic, a most tasty one, likewise a flash down below like Halley's comet, then a convulsive "Thank God! Cheer up, here's the door. O, Crumbs!...." When I reached the street Mr. Easy and companions had faded and gone. All was quiet. I found my way and wended it. The new club is determined upon getting the most eminent engineering prodigy of our land and age to join, but it is still on the waiting list.

WHAT THE GRADUATES ARE DOING

This section is conducted with a double object in view—First, to give the graduates professional news of each other; secondly, to give the undergraduates an idea of the possible fields of employment open to them in the future.

Walter Jackson, '07, is with the Ontario Power Co. on the construction of their second conduit.

N. C. A. Lloyd is employed on construction on the Canadian Northern Ontario Railroad on the Ottawa-Toronto line.

R. Pettingill, '06, has been transferred to the Port Colborne plant of the Canadian Cement Co., being in charge of the chemical department.

Frank G. Mace, '05, is employed in the Patent Office, Department of Agriculture, Ottawa, as Patent Examiner.

T. Harry Mace, '05, consulting engineer, Confederation Life Building, Toronto, is taking over the engineering office and business of Baker & Jordahl after being their chief engineer for a year and a half. His specialty is power lay-outs and transmission and reinforced concrete design.

J. F. S. Madden is with the Canadian General Electric Co. at Winnipeg.

K. G. Marlatt is at present in London, taking a post-graduate course at the Leather Sellers' Company Technical College.

C. H. Marrs, '02, is designing engineer for the Riter-Conley Mfg. Co., at Pittsburg, Pa.

D. W. Marrs, '06, is also with the Riter-Conley Mfg. Co.

W. A. Maxwell, '06, is with the Canadian Bridge Co., Walkerville, Ont.

D. D. McAlpine, '09, is with the General Electric Co. at Pittsfield, Mass.

A. S. McCordick is with the City Electrical Department, Toronto.

F. H. McKechnie is employed on construction with the National Transcontinental Railway, Cochrane, Ont.

H. L. McKinnon, '95, is chief engineer of the C. O. Bartlett & Snow Co., Cleveland, Ohio.

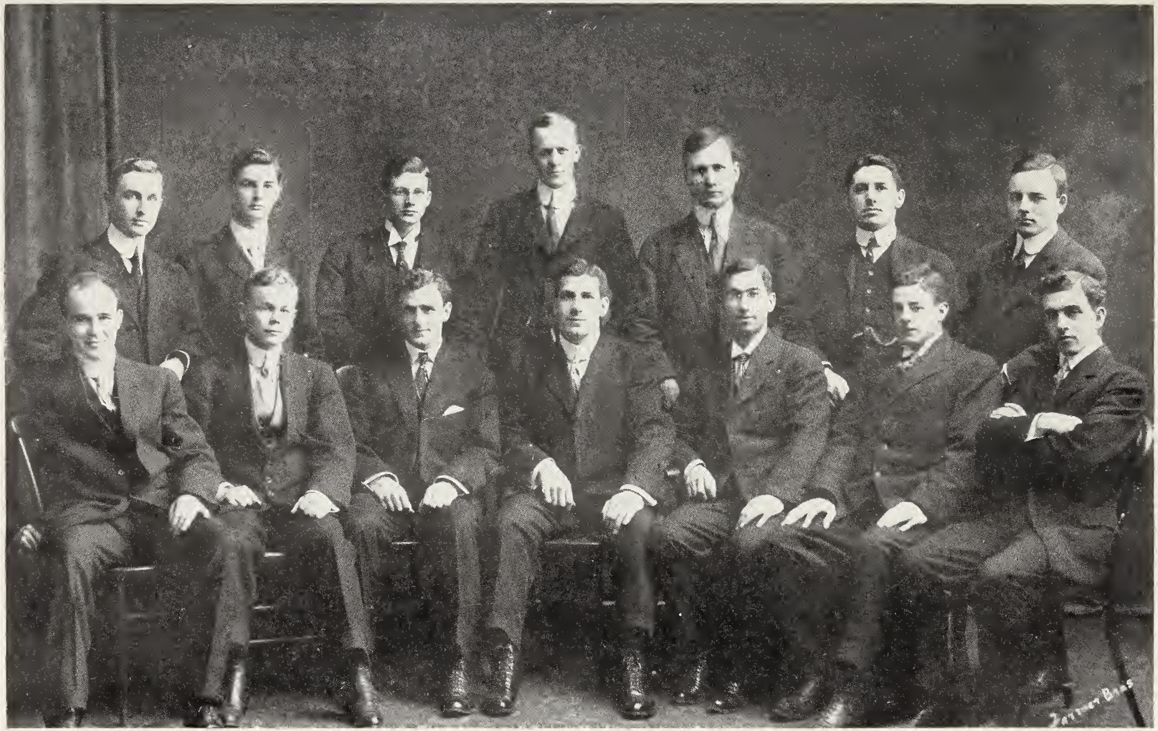
K. McQuarrie, '07, is assistant engineer on Maintenance of Way, Vancouver Division of the C. P. R.

H. G. McVean is at Moose Jaw, Sask.

L. H. Miller, '00, is chief sales agent of Bethlehem Steel Co. for Ohio and Michigan.

E. D. Monk, '08, is assistant chief of Testing Department, General Electric Co., at Pittsfield, Mass.

J. E. A. Moore, '91, is a consulting and contracting engineer at Cleveland, Ohio, specializing on the design and superintendence of manufacturing and power plants.



UNIVERSITY OF TORONTO ENGINEERING SOCIETY, EXECUTIVE COMMITTEE, 1909-10.

R. J. Fuller, 2nd Year Rep., E. J. Ritchie, Rec.-Sec., E. A. Jameson. 3rd Year Rep., H. W. Tate, 4th Year Rep., K. A. MacKenzie, B.A. Sc., L. E. Jones, Asst. Gen. Sec., J. Galbraith, 1st Year Rep., J. Burns, Cor.-Sec. F. V. Munro, Treasurer, G. Morton, 1st Vice-Pres., W. D. Black, Pres., H. W. Fairlie, Vice-Pres. Mech. Elec. Sec., J. C. Murton, Vice-Pres. Civil and Arch. Sec., C. G. Titus, Vice-Pres. Mining and Chemical Sec.

EDITORIAL BOARD "APPLIED SCIENCE" 1909-10.

C. G. Titus '10 W. D. Black '09 J. C. Murton '10 H. W. Fairlie '10
Saul Dushman, M.A. H. E. T. Haultain, C.E. K A. MacKenzie, B.A. Sc., Man. Editor H. W. Price, B.A. Sc. C. R. Young, B.A. Sc.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF
TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 APRIL, 1910 New Series Vol. 3, No. 6

A NOVEL REDUCTION GEAR

J. A. MacMURCHY, '96

Chief Draughtsman, Turbine Department, Westinghouse Machine Co.

Some six years ago a great interest was awakened in the question of the possible adaptability of the steam turbine to marine propulsion. The unusual interest was due to the fact that steam turbines were rapidly replacing reciprocating engines for driving electric generators, and great numbers of them of various sizes were in every-day use in power houses throughout this country and Europe. The popularity of the steam turbine seemed to be well founded, for it had proven itself more economical in steam consumption than the reciprocating engine, occupied vastly less space, required very little foundation, cost less to install, the cost of upkeep was small, and moreover it was extremely reliable in operation. These were the characteristics wanted in a marine engine, but it was not yet proven that they were the characteristics of a marine turbine, and it was to ascertain the exact status of the marine turbine that Mr. George Westinghouse retained Rear Admiral Melville, ex-Engineer in Chief of the United States Navy, and Mr. John H. Macalpine, consulting engineers, to investigate the matter for him. After they had obtained all the information that they possibly could upon this subject, they submitted to Mr. Westinghouse an exhaustive report which was not very favorable to the marine turbine. They pointed out that it would be injudicious to apply the turbine to other than very fast ships, which would run only a small proportion of the time at cruising speed, and even for such cases the advantages had, in their opinion, been over-rated.

They pointed out that the principal disadvantage of the steam turbine for marine propulsion was that even when the speed of revolution of propeller was so high that it was comparatively inefficient, the turbine was running at a speed which was slow for turbines and as a result marine turbines were bulky and not at all efficient as compared with land turbines. In concluding their report they say:

"If one could devise a means of reconciling in a practical manner the necessary high speed of revolution of turbine with the comparatively low rate of revolution required by an efficient propeller the problem would be solved and the turbine would practically wipe out the reciprocating engine for the propulsion of ships. The solution of this problem would be a stroke of great genius."

It is what we consider to be a solution of this problem that we wish to discuss in this paper, and it is interesting to note that this has been accomplished in a most practical manner by the very men who propounded it some six years ago. The necessary financial assistance to test the proposed device was in this case furnished by the man who instigated the investigation.

Various schemes have been devised to accomplish the speed reduction, one idea being to use a steam turbine to drive an electric generator furnishing power for motors on the propeller shafts. This scheme would have the advantage of extreme elasticity of arrangement as the turbine and condenser could be located where most favorable instead of having its position determined by the propeller shaft. This plan involves heavy and costly machinery, and moreover serious complication for varying the speed of the motors, an obvious disadvantage. The really fatal defect, however, is the loss of power in the generator and motor. Mr. Emmet in his paper before the Society of Naval Architects and Marine Engineers* claims that the efficiency of transmission, or, as he styles it, the "Electric Bond," should be about 92%. But Dr. Fottinger of the Vulcan Company of Stettin, who made a number of experiments with various electrical arrangements was not able to show a higher combined efficiency of generator and motor than 87%.

This low efficiency of electric transmission led Dr. Fottinger to look for other means of transmitting the power at a reduced speed, and he subsequently devised a very ingenious scheme which consists of two water wheels, one connected to the turbine and imparting velocity energy to the water and the other, which is coupled to the propeller, is designed to absorb the energy so developed. The latter doing this in two stages gives the desired reduction of speed. We understand that the Vulcan Co. have patented this idea and have conducted a large number of tests to determine the efficiency and practicability of the device. The efficiency as quoted in London "Engineering," November 5th, 1909, varies from 78% to 83%, depending upon the speed reduction.

The scheme proposed by Messrs. Melville and Macalpine is to use a high speed turbine and transmit the power to a slow speed propeller through a mechanical reduction gear.

It has been generally admitted that properly cut gears will transmit power with extremely small loss, but the use of gears for large work has heretofore been limited owing to mechanical difficulties involved. It, therefore, remained for Messrs. Melville and Macalpine to invent a gear which would transmit the enormous powers necessary for the propulsion of large, fast ships at a speed of revolution of pinion which would permit of a design of turbine giving the lowest possible steam consumption, and would reduce the speed of revolution to that required for best propeller efficiency. Ordinary gears will not do this: that is, they can not be operated successfully with wide gear faces working with several hundred pounds pressure per inch of width of tooth, while revolving at a velocity of over a mile a minute at the pitch line. And this for the manifest reason that if it was humanly possible to accurately cut and align the gears so that there would be a line contact to begin with, this condition would not be maintained for any length of time because of the natural wear of the bearings. Without this fine alignment the load would become concentrated at the ends of the teeth so that they would fail by breaking or would wear rapidly.

---

* Read at Meeting in New York on November 19th, 1909.

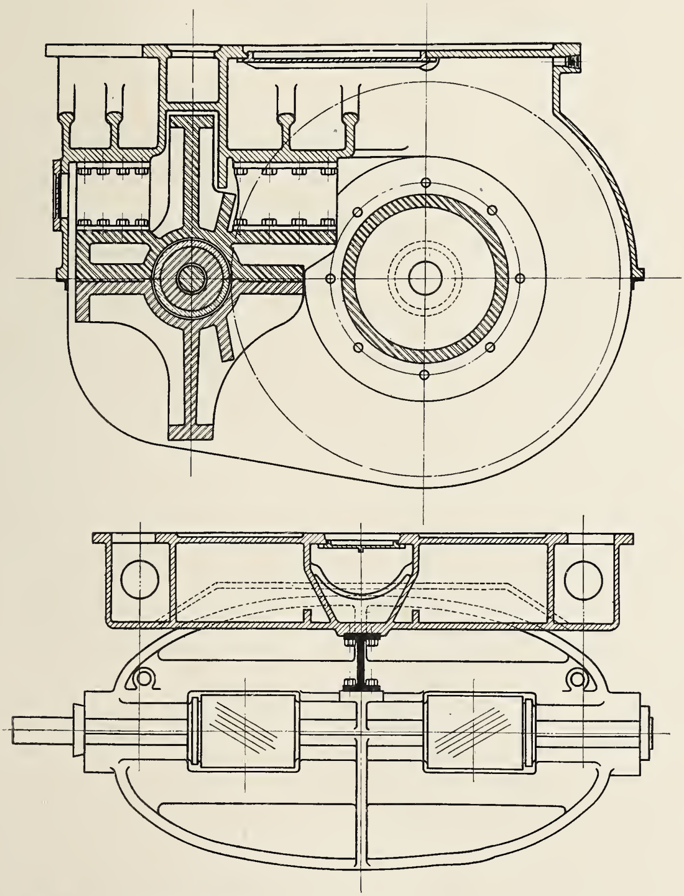


Fig. 1—Drawing showing Construction of Floating Frame.

High speed gears have been employed by the DeLaval Turbine Company for some time, but of limited power, as understood not greater than 300 H.P., or preferably less, while the demands for marine work may be twenty or thirty thousand horse power.

The novel feature of the Melville and Macalpine reduction gear consists in carrying the pinion shaft in what the inventors call a "floating" frame. Referring to Fig. 1 it will be noted that the floating frame is extremely stiff in itself and supported halfway between the end bearings in such a way that it is free to oscillate in the vertical plane passing through the axis of the pinion shaft—however, prevented from moving in other directions. The result of this arrangement is that any minute irregularity in the pitch of the teeth (which would tend to concentrate the load) will merely cause the floating frame to change its position about its central support and in this way equalize the pressure. It will be observed, therefore, that the pinions automatically adjust themselves to divide the load and so avoid abnormal stresses. In order to transmit the enormous power required in marine work, it is not necessary to have very wide gears, and it is found advantageous to divide this into two gears on the same shaft. Helical teeth are employed so that they will roll into contact without shock and thus reduce wear and noise. The helix described by the teeth on one gear is right hand and

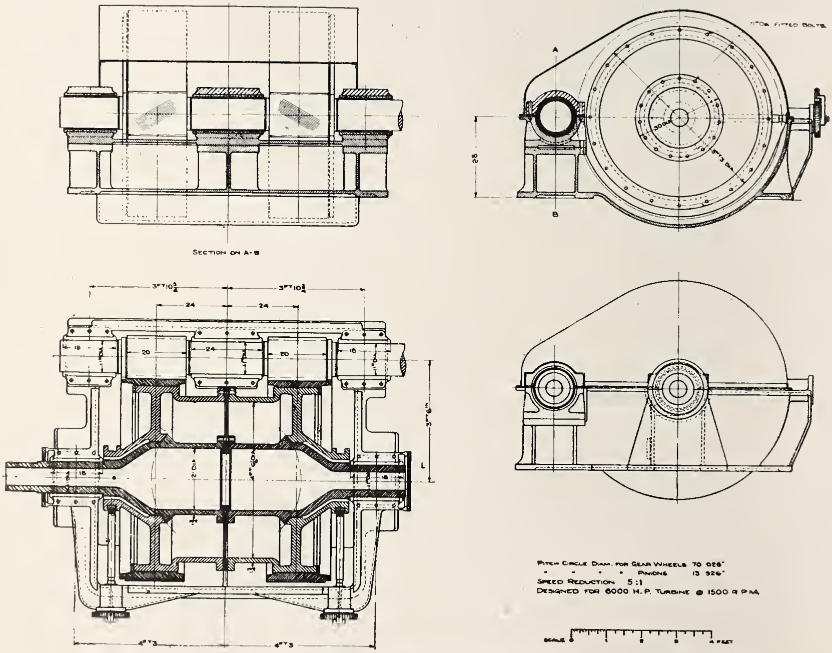


Fig. 2—Drawing showing Construction of Reduction Gear with Flexible Diaphragm.

on the other left hand so that the end thrust, due to the horizontal component of the pressure on the teeth, is balanced. In addition to this the pinion shaft is free to move endwise in its bearings so that it can not resist a greater end thrust at one end than at the other, and will therefore automatically divide the load between the two pinions. This feature made it necessary to design a special coupling which will be described later.

In this connection it will be interesting to note that Mr. George Westinghouse has developed a modification of this gear which differs from the "floating frame" type in that both the pinion shaft and the gear shaft are carried in fixed bearings, the connection between the gear rim and the shaft being made through a thin diaphragm, which while amply strong to transmit torque, is sufficiently flexible to permit of the gears aligning themselves by interaction of the tooth pressures. The general construction is shown in Fig. 2, the other details being the same as those described in connection with the "floating frame" gear.

The construction of the floating frame gear is illustrated in Fig. 3, parts being shown broken away to expose one of the pinions. It will be noticed that the flexible support of the pinion frame consists of an I-beam so arranged that the web is free to bend back and forth as required. Fig. 1 shows two sections through the main frame of this gear illustrating the arrangement of this I-beam and the floating frame a little more clearly. As this beam upon which the floating frame is supported, not

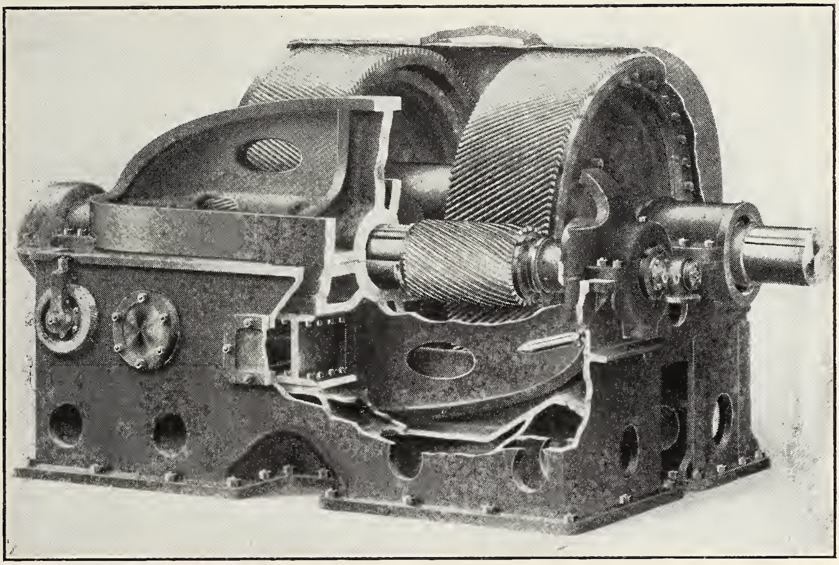


Fig. 3—Reduction Gear with Part of Floating Frame broken away to show Construction and Pinion.

only permits of a motion in the vertical plane through the centre line of the pinion shaft but is insufficient to resist the forces in a plane at right angles, consequently it is necessary to prevent motion due to this latter stress, and this is accomplished by having a strut placed at each end of the main bedplate between the latter and the floating frame as shown at Fig. 3. These struts are capable of being adjusted so that each pinion meshes equally with its main gear.

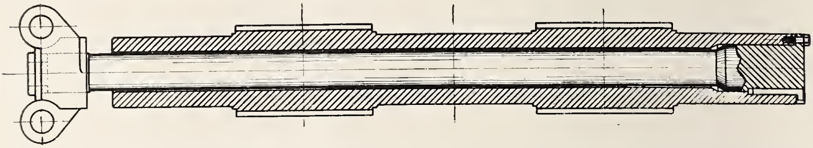


Fig. 4—Drawing showing Construction of Pinion and Flexible Pinion Shaft.

Fig. 4 shows the pinion and the pinion shaft separate from the gear and frame, and it will be noticed that the shaft passes completely through the pinion shell to the end farthest from the coupling and is here keyed and bolted. By virtue of its small diameter and length it becomes quite flexible, and offers little restraint to movement of the floating frame. It will be understood that this small shaft is amply strong to transmit the power

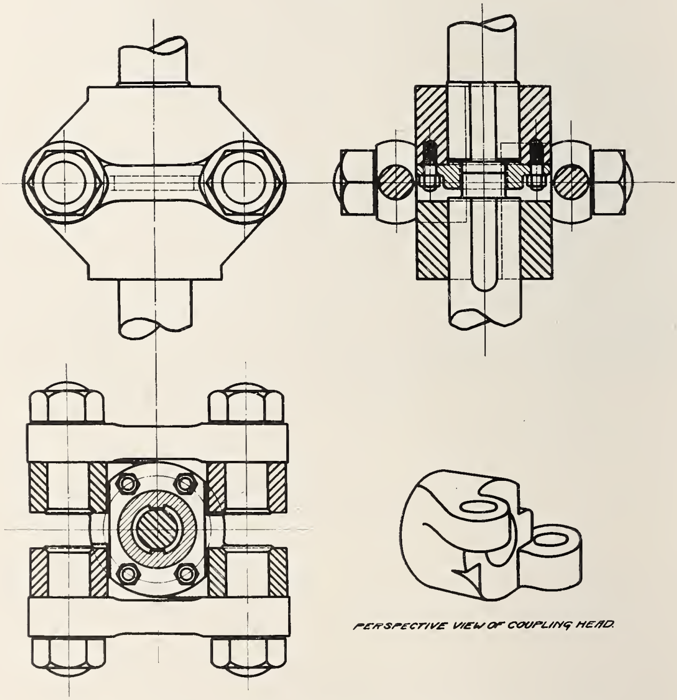


Fig. 5—Drawing showing Construction of Coupling.

of the turbine to the pinion shell on account of the high speed of revolution.

The coupling used between the turbine and pinion is shown in Fig. 5. It is obvious that this coupling permits of necessary freedom to end motion and is quite adequate for any small misalignment.

The lubrication of the teeth is effected by spraying oil on the pinion teeth just prior to the moment they come in contact with the teeth of the gear. This secures most efficient lubrication for the reason that the oil can only escape between the surfaces of the teeth in contact. The large quantity of oil so sprayed upon the teeth not only lubricates them but serves to effectively keep down the temperature. The oil is collected and cooled before being returned to the gears.

In order to determine the efficiency of the gear and ascertain what load it would carry, Mr. Westinghouse had one built and subjected to rigid and exhaustive tests. With his characteristic desire to obtain results, that would not be open to question, he had the gear built large enough to transmit 6000 H.P., this being as large as the boiler capacity of the Westinghouse Machine Company's power plant would permit of testing, and it was surely large enough to be considered full size and not an experimental model.

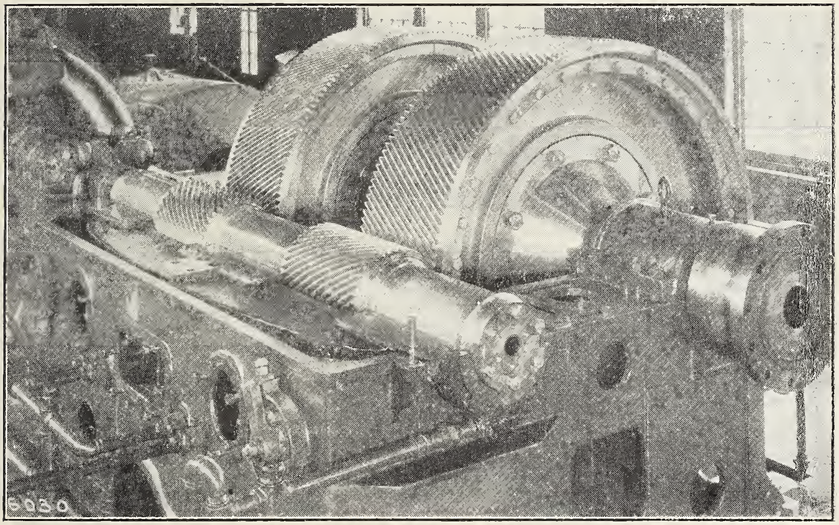


Fig. 6—Photo of Gear with Cover and Upper Half of Floating Frame Removed to Expose Pinion and Gear.

Fig. 6 shows a photograph of this gear with the cover and the upper half of the floating frame removed, a portion of the turbine which drives the gear being shown in the upper left-hand corner of the illustration.

The pitch diameter of the pinion is about 14″, and that of the large gear about 70″, the width of face of each being 20″. This particular gear was designed for a speed of 1500 R.P.M. of the pinion shaft, reducing to about 300 R.P.M. at the driven shaft. The pinions have thirty-five teeth each, and the large gears one hundred and seventy-six teeth, a hunting tooth being provided to equalize wear. The circumferential pitch of the teeth is 1¼″ and the helices described by the teeth are at an angle of 30° with the axis of the shaft. Involute teeth are used because they will permit of some latitude in the distance between centres of gear and pinion without any sacrifice of their operating qualities. The space occupied by the machine is approximately 11 feet long by 9 feet wide by 7 feet high.

On analyzing the forces in this gear, it will be found that in order to transmit 6000 H.P. there will be a pressure of 453 pounds per inch of length of tooth. It will also be noted that the speed at the pitch line is about 5500 ft. per minute.

The testing of this gear is an interesting problem, the method of solving which might be briefly discussed. A steam turbine capable of developing over 6000 H.P. at 1500 R.P.M. was connected to the reduction gear and the latter in turn was connected to a specially designed water brake capable of absorbing this power at 300 revolutions per minute. The tendency of the casing of the brake to turn is resisted by a radial arm attached to it and arranged to bear on a platform scale which would weigh the resisting force. This force, the length of the lever arm, and the speed of revolution of the brake rotor being known, the power transmitted may be calculated accurately by the familiar Prony brake formula. It is then only necessary to know the power supplied by the turbine in order to determine the efficiency of the gear in transmitting the power from the turbine to the brake, which in the case of the test was a substitute for the propeller that would ordinarily be driven from the gear shaft.

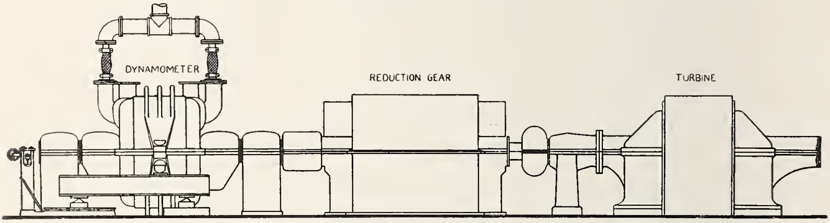


Fig. 7—Diagram showing Arrangement of Turbine, Gear and Brake during Test.

In order to establish the exact amount of power being transmitted by the turbine to the gear, advantage was taken of a characteristic of the steam turbine in transmitting a perfectly definite amount of power with a given pressure at the steam inlet as long as the speed of the turbine, the pressure in the exhaust and the quality of the steam remain constant. This fact made it possible to calibrate the turbine used by substituting for the reduction gear a directly coupled brake. Then, by operating the turbine at a fixed speed and by maintaining a constant vacuum in the exhaust outlet, the brake horse-power developed at certain inlet pressures was measured. On plotting a curve of the results obtained with different inlet pressures, a scale was created from which the horse-power corresponding to any inlet pressure could be easily read—as this line is almost straight, the readings between the points representing the actual observations could be determined with very considerable accuracy. The general arrangement of the turbine, gear and brake is shown in Fig. 7; the detail of the brake is given in Figs. 8 and 9. In testing the turbine the standard high speed brake used at East Pittsburg was employed.

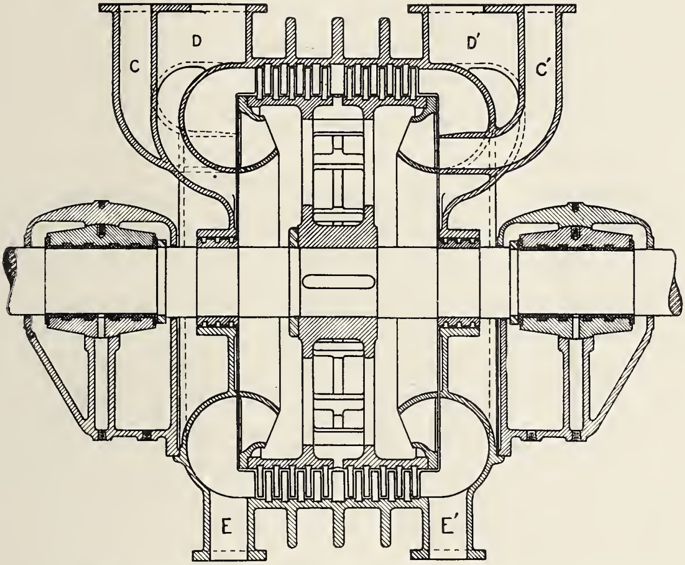


Fig. 8—Section through Brake used in Testing Gear.

Most careful (and several times repeated) tests demonstrated that the efficiency of the gear exceeds 98½%. As a check on the results so obtained the efficiency was again determined by measuring the quantity of oil circulated in the bearings and in spraying the gear teeth, and by keeping a record of the rise in temperature of the oil, the number of B. T. U.'s lost in friction was calculated.

It was found that the gear would transmit a load of 6000 H.P. at the speeds for which it was designed with only a moderate rise in temperature, and that there was no indication that this was near the limit of load which could be transmitted. The reason that more load was not applied was that the limit of the capacity of the turbine furnishing the power had been reached.

Having determined the efficiency and the load carrying capacity of this type of gear, the effect of its adoption for marine service incites a great deal of interest. To begin with more efficient turbines may be employed owing to the use of the higher speeds thus made practicable. For instance, careful tests of turbines of approximately the capacity of those of the *Mauretania* and *Lusitania* (when operated at speeds which the reduction gear will make possible for marine work) developed one B. H. P. hour on eleven pounds of steam per hour. On the other hand, while definite information is not available as to the steam consumption of the *Mauretania* and *Lusitania* turbines, it is believed to be at least 14½ lbs. per B. H. P. hour. Besides at the comparatively low speed of the turbines on these vessels, it still exceeds the speed for best propeller efficiency, probably an efficiency of only 55% obtains, while with reduction gear permitting the use of lower speed it is safe to say its efficiency may be made at least 65%. It is understood that the *Lusitania* uses 4700 tons of coal per voyage and the result of increasing the propeller efficiency from 55% to 65% would therefore mean a saving of coal amounting to over 700 tons. In addition, the more efficient high speed turbine would further reduce the coal consumption almost 1000 tons. This aggregates 1700 tons per voyage or a saving in coal alone of over a quarter of a million dollars per year on one ship.

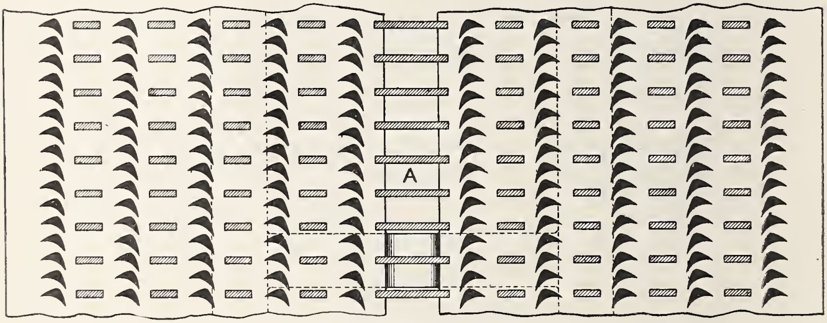


Fig. 9—Diagram showing Arrangement of Blading in Brake.

The effect of this increased efficiency of both turbine and propeller in a marine installation has an even farther reaching effect, as a large reduction in coal bunker capacity is also brought about and moreover the boiler H. P. required is reduced about one-third. On the *Lusitania* there are twenty-three double-ended and two single-ended boilers, the double-ended boilers being 17½ ft. in diameter by 22 ft. long, the saving of one-third of the space occupied by these boilers will be seen to be a very large item. As each of these ships carry 192 firemen and 123 trimmers, the reduction of the number of boilers to be fired would effect a very material reduction in the expense for this part of the crew.

In addition to the saving of space occupied by coal bunkers and boilers, the use of reduction gears will effect a great saving in the space required for the engine room. In the case of the *Mauretania* and the *Lusitania* this would amount to fully one-half of the present requirement.

While no estimate is presented of the increase in earning power due to the greater space for freight made available by the reduction in the size of engine room and space occupied by boilers and coal bunkers, it will be readily appreciated that this will also be a factor to be reckoned with.

There is another consideration which deserves mentioning, viz., if the increased space made available by the reduction in boiler and engine room and bunkers could not be profitably used the general proportions of the vessel might be decreased, which would immediately have an accumulative effect and again reduce the amount of power required for propulsion.

The requirements for warships are very different from those of fast passenger ships which run normally at full speed, as warships run at full speed only in case of emergency. When cruising they use less than one-fourth of full power. As the efficiency of the existing marine turbine rapidly falls off at reduced (rotative) speeds the steam consumption per H.P. hour becomes serious when the ship is running at cruising speed. The desideratum is therefore a turbine capable of performing economically at both cruising and full speed. Realizing the inadequacy of the present marine turbine to fulfill this requirement, Mr. Westinghouse has brought out a design which will give almost as good economy at low speeds as at the higher speeds. This is accomplished by a very ingenious type of valve gear controlling one set of nozzles and blade passages for full speed and an additional set for cruising speed—obviously required for the reason that the velocity "abstracting power" of the blades reduces with the lower peripheral speed, due to the steam leaving the wheel at higher velocity. In the design referred to the steam is redirected upon the blades as often as necessary to efficiently utilize the velocity of the steam.

It has already been pointed out that in the case of the merchant ships a great saving may be effected in the steam consumption and consequently in the cost of coal and the space required for the equipment and coal storage. Now, for the warships not only the same advantage obtains but an additional and very important gain over present practice may be realized by thus increasing the possible cruising radius. This is of inestimable value from a strategic standpoint.

Doubtless many other uses will be found for this reduction gear, one of which will surely be to drive large D. C. generators with turbines, but if it had no other use than for marine work, it must be looked upon as a very great achievement, and as marking an epoch in the history of marine engineering.

NOTES ON ARCHITECTURE.*

H. F. BALLANTYNE, B.A.Sc., '94

I am asked to say something to you on an architectural topic. To comply with this request I might select some building and describe to you the various problems that presented themselves in planning for its construction and the manner in which they were met; but, this method of procedure is objectionable in that it would leave many of you without any definite idea of what architecture is or what it means, for I take it that only a few of those present have given the subject of architecture serious thought.

In considering still further what I might say to you at this time my mind naturally went back to such experiences as I have had when dealing with engineers in matters architectural, and I was reminded of differences in the point of view from which a building project is regarded by the Architect and the Engineer with the resulting differences of opinion that sometimes exist between them, as to the object to be attained and the best method of attaining it.

Knowing that the Engineering Society is composed chiefly of men preparing for various branches of the engineering profession, I thought I might render both Architectural and Engineering students some service in that while trying to stimulate the interest of the architectural student I might aid the engineering student to some general knowledge of the subject in a way that might be of practical service to him should he engage at any time in the erection of buildings of an architectural character.

The subject of architecture is a large one and we cannot hope to cover it, in even the most superficial manner, at this time; we will therefore confine our attention to an effort to determine what architecture is and illustrate some of its essential features by means of historical examples.

Architecture has to do with building, the subject frequently being divided into Civil architecture, Military architecture and Naval architecture. In what follows, military architecture, the building of forts and fortifications; and naval architecture, the building of ships will not be considered. We will confine our attention to Civil Architecture, which we will understand to include houses, churches, schools and college buildings, libraries, legislative and other buildings of a like nature to these, in which an effort is made to embody the architectural quality.

---

* Address delivered before general meeting of Engineering Society, February, 1910.

Before going further, let us try to define architecture and so better understand what is meant by architectural quality.

From an examination of numerous hand-books on the History of Architecture one might infer that architecture is somewhat difficult to clearly define. One very eminent authority, Viollet-le-Duc, defines architecture as the "Art of Building." Another, Prof. Fletcher, an English author, defines architecture as "Construction with an artistic motive."

Professor Hamlin, of Columbia University, New York, in his history defines architecture as "The art which seeks to harmonize in a building the requirements of utility and beauty." He further states that the erection of structures devoid of beauty is mere building, a trade, not an art. Edifices in which strength and stability alone are sought and in designing which only utilitarian considerations have been followed, are properly works of engineering. Only when the idea of beauty is added to that of use does a structure take its place among works of architecture.

This last definition is, I think, best for our present purpose. To say that architecture is the "Art of Building" requires further explanation to have much meaning to many of us. That architecture is the art which seeks to harmonize in a building the requirements of utility and beauty conveys the further idea that a building to be architectural must meet or serve the purpose for which it is erected in a direct and practical manner; also that the different divisions or masses of the building must bear such relations to each other both in size and form as will be pleasing, the wall surfaces and roofs, the door, window and other openings must be correctly proportioned and spaced. The materials of construction must be obtainable at reasonable cost, be durable, but not too hard to work, must also have sufficient strength and good surface or texture; each material must be of pleasing color and the different materials of colors that will look well together. Ever keeping before us the fact that the building must be constructed of available materials, by workmen often of only moderate skill, and having made provision for all requirements of utility, the masses, sub-divisions and details must be so related to each other and the construction so refined and perfected that the whole will possess at least some elements of beauty.

It is agreed then, that a building to be classed as architecture must meet both these requirements of utility and beauty. This utility and beauty is obtained in a structure, the product of skill and labor applied to materials provided for us by nature.

All architecture is based on a very few fundamental principles and I wish to devote the greater part of the time that remains in an attempt to show that all essentially good architecture is not the product of the mere fad or fancy of the architect or designer, but is based on fundamental principles which govern and must be followed.

These fundamental principles (*) are structural, are four in number and are commonly designated by the method employed to cover an enclosed space, as follows:

1. Lintel or beam construction.
2. Arch and vault construction.
3. Truss construction.
4. Cohesive construction.

In lintel construction a single cross piece or beam rests on walls, piers or columns, and is subjected to transverse stresses.

In arch and vault construction, several pieces commonly of stone are made to span an opening between two supports. These pieces are in compression and exert lateral thrusts which must be taken up by the massiveness of the abutments or by counter thrust from other arches or vaults.

In truss construction, a frame work is built up with pieces of wood or steel in a form to resist the stresses to which it is subjected, the whole truss forming a compound lintel or beam.

The fourth system of construction, that of cohesion, employs concrete placed when plastic in moulds or forms, which on setting or hardening produces a solid and rigid mass. Concrete itself having little tensile strength, is, when necessary, reinforced with steel rods, bars or wires buried in the concrete, producing reinforced concrete.

Architecture is based on the use of one or more of these four structural principles; which structural principle or system of construction is used, depends in each case upon the materials of construction to be employed.

When large flat stones of considerable tensile strength are available, we find, as in early times, that lintel construction in stone is common. Timber also from a very remote past has been obtainable for beams. At the present time, except for minor work, our lintels or beams are of steel.

Where simple timber or steel beams are not suitable we form them into trusses.

When, as in the not distant past, iron and steel were not obtainable for this purpose and timber was either scarce or avoided on account of its destructibility, stones of moderate size were used in arch and vault construction. When a good cement is obtainable and sand and gravel or broken stone is available, concrete is at our service.

Our main purpose at this time being to show that fundamentally, good architecture is based on good construction, we will omit any reference to detail of forms, mouldings or ornament. We will also pass over any reference to plumbing, heating, electric lighting and other work of a similar nature, which though ordinarily necessary, are in the nature of equipment. Neither will we consider planning except incidentally and in reference to providing points of support.

Let us now examine some examples of the architecture of the past and note how the principles of construction already spoken of were employed.

---

* See Hamlin's History of Architecture.

The earliest architecture of which we have any definite knowledge is that of Egypt, and is of the lintel type of construction.

The Egyptians by 6,000 B.C., or 8,000 years ago, had attained a high state of civilization and were well skilled in the arts.

The earliest remains are chiefly tombs, the famous pyramids dating from about 4,000 B. C., themselves being the tombs of the Kings. The grand age of architecture in Egypt is, however, in the time of the New Empire, so called, dating from 1588 to 1150 B.C. During this period the buildings are chiefly temples.

The great temple at Karnak is one example and its plan shows the typical arrangement of an Egyptian temple with its entrance pylons and surrounding outer wall. We enter a doorway between these pylons into an outer court surrounded by columns; beyond this is a hall or room with many columns and beyond this still other chambers and passageways leading to the inner and most sacred part of the temple.

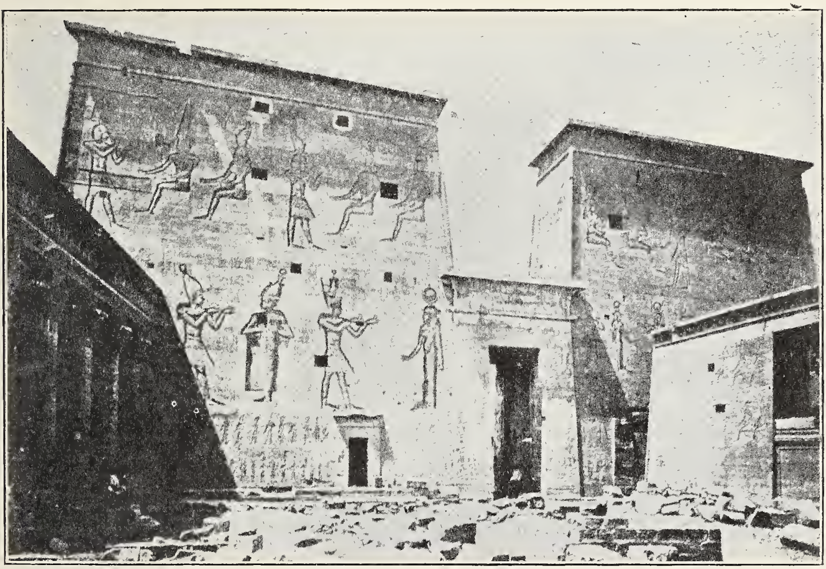


Fig. 1. Temple at Philae

This particular temple is an enormous structure, its extreme length being 1,215 feet and its greatest width 376 feet; but, the particular part to which I wish to draw your attention is the great Hypostyle Hall, "the noblest single work of Egyptian architecture," which covers an area 340 feet by 170 feet, and contains 134 columns in 16 rows, which support a massive stone roof. Stone lintels are carried across from column to column and upon these are placed the large stones which form the roof covering. Through the centre of this hall you will also note two rows of columns each 70 feet high and 12 feet in diameter which support a roof at a higher level than the rest. This forms what is known as a clear-storey and shows an attempt on the part of the Egyptians to light this hall in a manner that we shall see was used with good effect at a much later date.

Contemporary with Egypt, and of as great age, was the civilization of Caldaea and Assyria in the Valleys of the Tigris and Euphrates Rivers. Both stone and timber were scarce in these countries and their architecture is only of secondary importance. The Assyrian Empire was succeeded by the Persian in the 6th century B. C. Persian architecture was much influenced by the architecture of Caldaea and Assyria and by that of Egypt as well; but, none of this Asiatic architecture is of much interest to us, beyond the fact that some progress was made in the use of arch and vault construction.

It is to Greece that we must now turn for our examples of lintel construction.

During the time that the Great Temples of which we have spoken were being built in Egypt, the land now known as Greece and also the Coasts of Asia Minor were inhabited by nomadic and sea-faring peoples who traded freely with each other and with the Egyptians and became acquainted with the great architectural monuments of Egypt.

The early Greek architecture is heavy and somewhat rude; but, following the wars with the Persians in the early part of the 5th century B. C. a great period of prosperity ensued and we find great attention paid to art and architecture.

Greek architecture like the Egyptian was of the purely lintel type of construction; but, in plan the Greek temple is very different, for whereas the Egyptian temple was surrounded by a massive stone wall with the columnar construction inside, in the Greek temple an inner chamber is surrounded by a great colonnade which with the light and shade of a southern climate produced a very striking and impressive appearance.

The most perfect examples of Greek architecture and of lintel construction are found upon the Acropolis at Athens and include the Parthenon and the Erechtheum.

The Parthenon was the temple of the Goddess Athena, in plan 102 feet by 228 feet, with two rooms or chambers and a portico at either end, the whole being surrounded by a colonnade, each column about 34 feet high and supporting architrave, frieze and cornice of lintel construction.

The Erechtheum, located near the Parthenon, though very irregular in plan, also shows the use of lintel construction.

The ancient Greek, like the modern Britisher, was a seafaring man and a traveler. He established colonies in many places upon the shores of the Mediterranean, and built many temples so that the Greek form of lintel construction became familiar throughout that entire region.

The success attained by both Egyptians and Greeks in the use of lintel construction was largely due to the possibility of obtaining stones of very large dimensions. Sandstone and syenite were used by the Egyptians while the famous Pentellic and other marbles were obtainable at Athens and many other places throughout Greece.

But the limitations of this system of construction are shown in the difficulty the Greeks had to provide proper roofs for their buildings. They did not care to fill the interior of their buildings with columns as the Egyptians had done, and resorted to the use of timber beams to span wide spaces with the result that the roofs of the Greek temples have long since been in ruins.

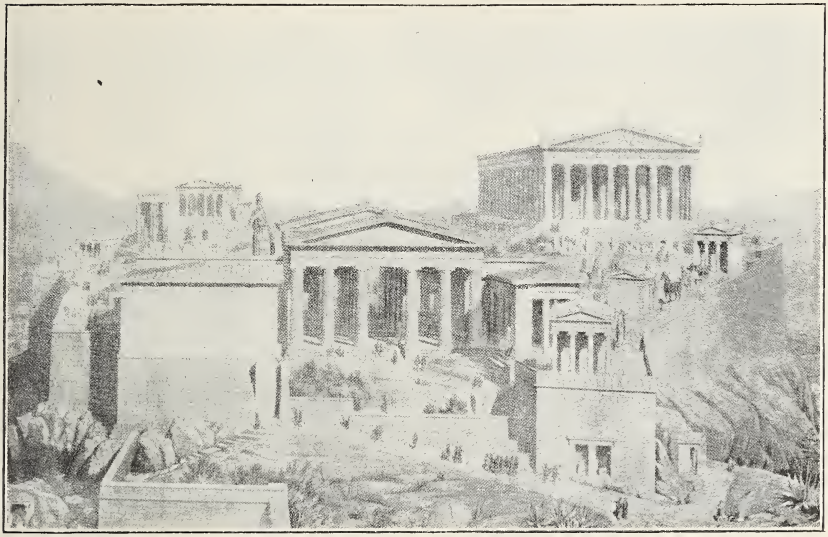


Fig. 2. The Acropolis at Athens

For further light on this subject of construction we must turn to the buildings of the Romans.

Before the time of the Romans and during the time when the Greeks were erecting their finest buildings, the central and northern part of Italy was inhabited by a people of prehistoric origin and known as the Etruscans.

The Etruscans had reached an advanced state of civilization, were great engineers and builders and made free use of the arch and vault in their building operations.

Arch and vault construction was known of, at a very early age; the use of the arch also was not unknown to the early Greeks; but with excellent marble to hand, they chose to employ the lintel method of construction and made little use of the arch.

It was otherwise with the Etruscans and their successors, the Romans, and it is to Rome that we must look for the first practical use of the arch and vault, the second system of construction which we are to consider.

The Romans though seemingly lacking in culture were wonderful organizers and administrators. By about 300 B. C. they had overcome the Etruscans and other kindred peoples and became the masters of Italy. In 146 B. C. Greece was made a Roman province.

The Etruscans were engineers and builders and the Greeks artists. The practical Romans, as administrators and men of affairs, directed the efforts of these engineers and artists to evolve from the architecture of their predecessors a mighty architecture adapted to new and novel conditions. They constructed buildings suited to a great variety of new requirements and made the arch and vault the basis of their system of construction. They systematized their methods of construction so that soldiers and barbarians could erect the rougher parts of their buildings while the decorative details were standardized and simplified so that workmen of moderate skill could execute them. The Romans, too, were expert planners and displayed their genius in the great variety of arrangement and plan of their buildings, always keeping in mind the requirements of construction, convenience and artistic effect.

Such was the character and genius of this people who were to take up the science and art of building when the Greeks had carried lintel or beam construction to its greatest perfection.

We have noted the difficulty which the Greeks had with the roofs of their temples. Let us now examine the Roman method of meeting this difficulty.

In the Basilica of Constantine erected at Rome in 312 A. D. we have an advanced example of Roman vault construction.

Basilicas were erected by the Romans as halls of justice and as exchanges for merchants, and comprise some of the finest buildings erected by them.

In the Basilica of Constantine we find a somewhat elaborate system of vaulting. The side compartments are covered with barrel vaults placed at right angles to the main axis of the building and the central portion or nave is covered with intersecting barrel vaults forming at their intersections what are called groins; these vaults are therefore called groined vaults.

In one of the halls of the Baths of Diocletian we have another example of Roman groined vaulting.

These examples and many others which we cannot mention show the ingenuity of the Romans as constructors. In Italy and in the provinces it was often difficult to obtain large stones, the time consumed woud also be considerable. By the use of arches and vaults, smaller stones could be used, even the lintel forms being built up of small stones and supported on masonry arches.

It will be observed that the Roman vaults were semi-cylindrical in section, either the simple barrel vault or the groined vault being used to cover corridors and oblong halls.

At the time the Basilica of Constantine was erected, 312 A. D., conditions were preparing for a change; Christianity had developed great power. The Emperor Constantine himself professed Christianity and the Christians who up to this time had been an unpopular religious sect, were now able to hold their services openly and freely.

In 324 A. D. Constantine removed his capitol from Rome to Byzantine which hereafter is called Constantinople.

The architecture developed at Constantinople is known as the Byzantine style. We cannot discuss this style further than to state that domes instead of vaults were used to cover their buildings; this system of construction, a modified form of vault construction was the forerunner of the modern dome of which the dome of St. Peter's at Rome, the dome of St. Paul's Cathedral in London and still more recently, the dome of the Capitol at Washington are examples.

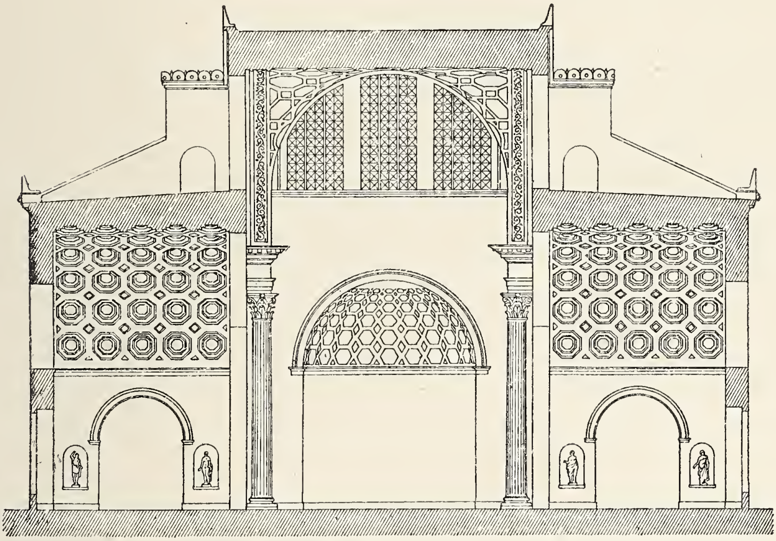


Fig. 3. The Basilica of Constantine

In Rome and other places in Italy and Western Europe the early Christians adopted the plan of the Roman Basilica for their churches, but without the vaulted roofs.

From the early part of the fourth century Christianity, through the Church of Rome, became the great promoter of civilization and the arts of Western Europe, and it is to churches and monastic buildings that we must look for progress in the art of building.

Though the Western Roman Empire came to an end in the latter part of the fifth century A.D., the buildings of the Romans continued to be the models for those constructed for several centuries afterwards. For almost five centuries, however, the progress of architecture in Western Europe was very slow and it is not until the tenth and eleventh centuries that this new architecture of Western Europe, and known as Romanesque, becomes of great importance.

In the 10th and 11th centuries conditions had so improved that we find the priests and monks in Italy and Western Europe trying to build churches of stone in which the general plan of the Roman Basilica appears in simpler and more massive form and so far as possible of fireproof construction.

Numbers of these buildings were erected in Southern France where Roman remains are numerous.

Two well-known examples of Romanesque vaulting of a late date and of an advanced type are also found in Northern Italy in the churches of San Ambrogio at Milan and San Michele at Pavia.

In these, as in earlier examples, the nave is divided into square bays by transverse arches and the space between is covered with groined vaults. Between the large main piers in these examples, however, are smaller piers with arches in two storeys carrying a wall above, which in turn supports the roof.

The great difficulty with all this vaulted construction is to take care of the thrust of the vaults and this may have been one reason why the Greeks did not use this form of construction.

Amongst the Romans, in some cases, by sheer mass of masonry in the side walls they resisted this thrust which in a barrel vault is distributed equally along the entire length of the side walls; in others by internal buttresses or pilasters and the assistance of an outer wall or colonnade they secured stability. In still others, as in the Basilica of Constantine, they concentrated the thrusts at definite points and by building cross vaults at right angles thereto, the thrusts at these points are taken up.

The Romanesque builders also struggled with this problem of thrusts, with more or less success, when the centre was not carried up into a clear-storey. The need of the clear-storey, however, increased their troubles and many of the early structures with clear-storeys fell down.

Two remarkable churches in which vaults with clear-storeys were successfully constructed, are situated at Caen in Normandy, France. These are the Church of St. Etienne (Abbaye Aux Hommes) and the Church of La Trinité (Abbaye Aux Dames) built for William the Conqueror, in 1066 A. D., the same year in which he crossed over into England.

The plan of St. Etienne shows the nave divided into square bays with the side aisles sub-divided in a manner very similar to that employed in the Churches of San Ambrogio and San Michele. Here, however, the large vaulting bays are divided across the middle by arches which divide the vaults, each into six parts, producing what is known as the six part vault. The vaults in general are semi-circular in section and the windows round-headed.

In these churches the thrusts of the vaults are concentrated at double the number of points possible with the square vault and by means of small external buttresses and internal bracing the thrust of these vaults has been resisted now for almost 900 years.

These churches at Caen, in style, are the Norman version of the Romanesque, sometimes called Norman Romanesque or simply Norman, and are the immediate predecessors in point of time of the Norman architecture of England, of which numerous examples still exist.

The expedient of the six part vault as found in these churches of Normandy, though in use for over 100 years, was not satisfactory; the masonry was still heavy, the windows small and the lighting poor; the form of the six part vault also is awkward.

The problem before the architects and builders was therefore to devise a better method of vaulting, one in which less masonry was required both for economy and to obtain more window space, a method by which the thrust of the vaults could be taken up and at the same time produce vaults of more artistic and pleasing appearance.

These conditions were finally met in a very ingenious and logical manner in Central and Northern France, between the years 1150 and 1500 A. D.

The Frenchman of that time, as now, was an ingenious and daring individual and very logical. He, by employing two principles, which had been made use of in a limited way by the Roman and Byzantine builders, solved the problem.

The first of these principles was the concentration of the thrusts of the vaults upon isolated points of support by means of groined instead of barrel vaults, in a manner similar to that employed in the Basilica of Constantine. By this concentration of thrusts upon isolated points it was possible to support the vaults upon piers. The walls between the piers or buttresses, became a mere filling which was often in great part replaced by immense windows filled with stained glass.

Having concentrated the thrusts of the vaults upon isolated points, it was necessary to take up the thrusts at these points. This was accomplished by building half arches over the side aisles to buttresses in the outer walls; by this means the thrusts were generally brought sufficiently low to ensure stability, if not, additional weight was added to the buttresses in the form of pinnacles. This combination of the half-arch and buttress is called the flying buttress and "is the one absolutely novel and distinctive feature of this style which is known as Gothic."

These two principles, the concentration of the thrusts of the vaults upon isolated points of support, and the taking up of these thrusts by flying buttresses formed the structural basis of the Gothic styles, but their application lead to the introduction of two other principles of almost equal importance. These are ribbed vaulting and the pointed arch.

The difficulty of building centering for intersecting barrel or groined vaults was considerable. If the intersecting vaults are of the same height and semi-cylindrical in section, the intersections or groins lie in vertical planes and are elliptical in section. Under these conditions the Romanesque architects conceived the idea of constructing these intersections first, forming skeleton vaults with ribs of stone; the spaces between these ribs were then filled in with comparative ease, the ribs helping to support the centerings for each of the four or more compartments of a vaulting bay.

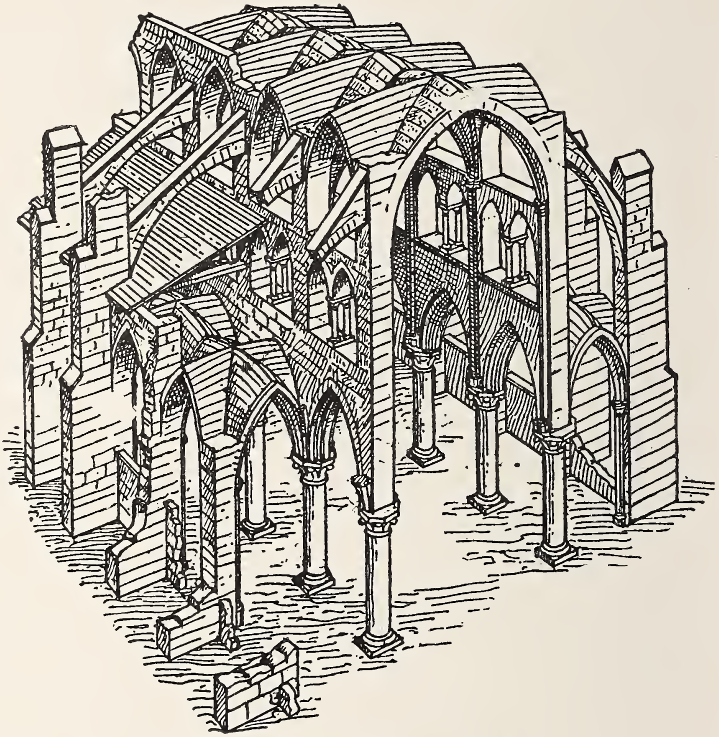


Fig. 4. Gothic Construction

But it was not always possible to keep the vaulting bays square as is required if semi-cylindrical vaults are to intersect in vertical planes. To remedy this difficulty when the vaulting bays were oblong instead of square the pointed arch was adopted.

By this expedient vaults of varying widths could be brought to the same height; the diagonal ribs were commonly made semicircular with the intersecting vaults more or less pointed.

The spaces between the ribs are slightly warped surfaces; but, this was not so great that it could not be taken care of in the construction of the separate compartments of the vault.

The pointed arch was thus introduced as the most convenient form for the construction of the vaulting ribs and was soon applied to other parts of the structure from necessity, as where it is necessary to make window openings fit the spaces between the vaults, or from a desire for uniformity in the style of the openings.

This entire system of vaulting, constituted the inner roof or stone ceiling of the building, generally a church or a cathedral, and was covered over with a timber roof to protect it from the weather.

This Gothic style, the architecture of the flying buttress and the pointed arch was the sequel or outgrowth of the Romanesque styles which had preceded it and these Romanesque styles in turn were founded upon Roman models.

Vault construction with its problems of thrust and counter thrust as met with by the Romans was thus developed by slow stages during the Romanesque period and was worked out and reached its final solution in the magnificent Gothic cathedrals of the 13th and 14th centuries in Western Europe.

Thus far we have confined our attention to buildings embodying the structural principles of the lintel and the arch or vault, and have tried to show, that of all buildings constructed in which the lintel system of construction was employed, the architecture of the Greeks was the highest development, the Parthenon on the Acropolis at Athens built in the 5th century B. C., having been the most perfect example.

Following the Greeks we found the Romans, about the beginning of the Christian era, incorporating the principle of the arch and vault with that of the lintel. The architecture of the arch and vault after a long period of evolution reached its final and logical conclusion in the Gothic architecture of North Central France in the 13th and 14th centuries. Of this Gothic style, the cathedrals at Amiens and Rheims and that of Notre Dame in Paris are examples.

Further, in our discussion of lintel and vault construction we have dealt with structures of masonry. Our illustrations have been temples, basilicas, cathedrals, buildings of an imposing and monumental character. Even in some of these, the lintels, as for example the supports for the roofs of the Greek temples, were probably of timber. Many of the English cathedrals and churches, were not vaulted and even when vaulted, the vaulting had to be protected by timber roofs. The use of timber brings us to a consideration of our third system of construction, that of the truss.

Timber was undoubtedly used from a very early age, but wood being of a perishable nature, ancient examples of its use are not in existence and our knowledge of how it was employed is therefore meagre.

Carvings on Egyptian monuments show tombs evidently designed to imitate wooden models and the Egyptians, doubtless, lived in houses constructed of wood.

In Western Asia, along the shores of the Mediterranean Sea, lived the Phonecians and others, builders of ships and skilled in the use of wood; their rock cut tombs are constructed after models in wood. The Greeks, too, were a sea-faring people. They, therefore, were also builders of ships and skilled in timber construction. Wood, doubtless, was used freely in their less important structures. When we come to the Romans, though no examples of their work in wood remain; we know that they were well skilled in working with timber and in carpentry.

But it is the timber construction of the late Romanesque and Gothic periods of the 12th and 13th centuries and later that most interests us for of this many examples are still to be found in Northern France, in England and in Germany.

The timber construction of the Middle Ages was based on Roman models, the material employed being heavy squared timbers of oak, a wood which was plentiful in Northern Europe at that time.

Timber construction was used in conjunction with masonry or alone. All of the cathedrals, as has been said, even when vaulted in stone, were covered with wooden roofs. In the castles and other secondary buildings, the floors were of wood supported on heavy beams, while the roof construction was of timber supported on wooden trusses.

In minor buildings, such as houses and shops, the entire structure above the foundation, was framed up in timber, and in the Middle Ages, the towns of Northern France, England and Germany were filled with buildings of so-called half-timber construction in which the spaces between the beams were filled with masonry or plaster.

The timbers were framed with mortise and tenon, the joints being fitted together with great precision and secured with oak piers; spikes and bolts were never used.

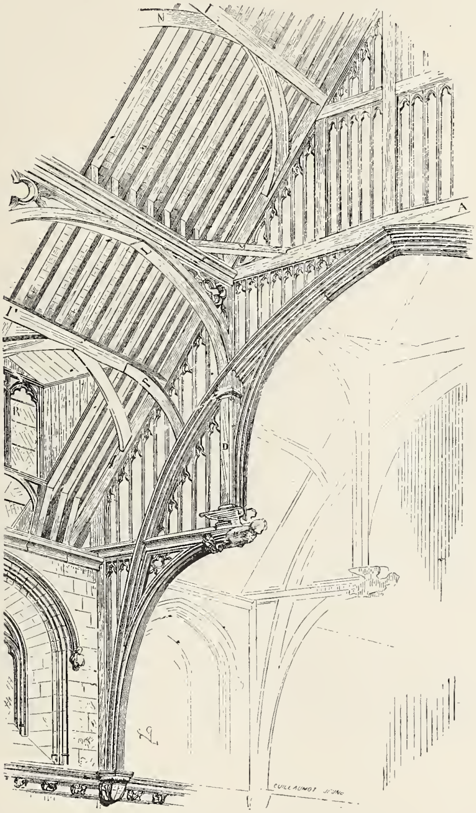
The most interesting examples of timber framing in the Middle Ages are shown in the construction of the roofs.

Roofs are of two kinds; in the one the timber framing is exposed on the inside and in the other it is hidden from view by some form of ceiling. In this latter case little attention need be paid to appearances, the aim being a strong and economical construction; with exposed trusses and roof timbers it was otherwise; here care was required in both form and construction to secure both strength and pleasing appearance.

Though somewhat timid in the use of stone vault construction the English were very successful in building timber roofs. Probably the finest timber roof in existence, is that of Westminster Hall, London, with its series of hammer beam trusses built in the reign of Richard II.

Trusses of timber were used almost exclusively down to the latter part of the 19th century when the introduction of wrought iron and steel brought about a change. Now, except for minor buildings, our trusses, and even the frames of some of our buildings, are of steel.

Our fourth principle of construction, that of cohesion of materials, has to do chiefly with the use of concrete, in this later day reinforced with metal when required to take up tensile stresses which this material is not well suited to resist.



No. 5. Hammer Beam Truss

The use of concrete is both a very old and a very new art. It was employed by the Romans 2,000 years ago and by ourselves chiefly within the last 20 years. The Romans found the materials for a good hydraulic cement ready to hand; while, we, having learned to make good Portland cement from lime and clay, can obtain a good cement in large quantities in almost any place and at moderate cost.

The Romans were provided with a much greater variety of building materials than the Greeks. In Greece, the chief and almost the only building material was marble. In Italy, marble, terra cotta, stone and brick were largely used; besides these, lava and pozzolana, the products of volcanic eruptions, and excellent sand and gravel were plentiful. It is with these latter materials that we are now most interested.

Pozzolana is a clean sandy earth which when mixed with lime produces a good hydraulic cement, and this cement mixed with small or broken stones, pieces of bricks or other debris produced the concrete of the Romans.

Roman concrete so-called is in general of two kinds; in the one the materials are mixed much in the manner of modern times; in the other small sized stones were placed in a heavy bed of fresh mortar in the wall and pressed down into it. In either case the resulting mass is much the same.

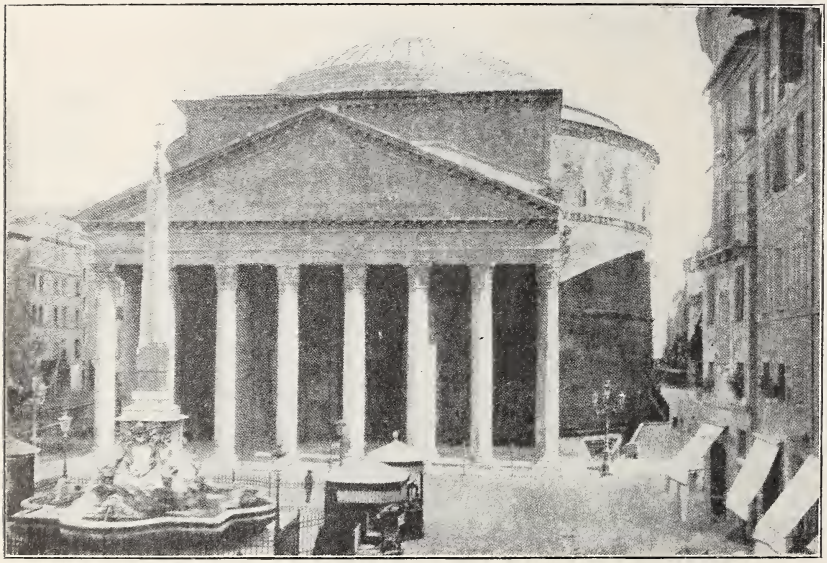


Fig. 6. The Pantheon at Rome

One of the most celebrated buildings of antiquity, the Pantheon at Rome, is of this latter form of construction. The Pantheon is circular in plan, 142 feet internal diameter and the same in height with walls 20 feet thick. The roof is in the form of an inverted saucer, with an opening at the top 27 feet in diameter by means of which this vast interior is lighted.

In construction this dome, brick or tile ribs with cross ties were built on comparatively slight centerings of timber and this system of brick ribs formed the support for the concrete placed upon it; thick and heavy at the haunches and lighter towards the top.

Other Roman buildings, as the Basilica of Constantine, the Baths of Caracalla and of Diocletian had vaults of concrete or massive masonry in which the cohesion of the cementing material greatly reduced the thrusts upon the supporting walls.

This Roman manner of using concrete depended on being able to obtain materials for a natural hydraulic cement. These materials were plentiful in various parts of Italy but not common elsewhere. As a result little use was made of concrete construction outside of Italy until recent times when from certain stones it was found possible to make hydraulic limes and cements. Still more recently, with the advancement of science and with improved appliances, excellent Portland cements are made in many sections of this and other countries.

Cement and reinforced concrete construction is now common and we are all more or less familiar in a general way with the manner in which it is employed. Architecturally there are still several difficulties encountered in the use of concrete; buildings being more or less irregular in outline it is difficult to make the forms required. There is also the further difficulty of obtaining pleasing surfaces on the exposed walls. Whether a house made of concrete is sufficiently free from dampness is still another question.

On the whole the employment of concrete for buildings is still in its early stages, its use being confined chiefly to footings, foundations and floors.

For bridge abutments, retaining walls and other places where the forms are simple, and appearance and dryness of secondary importance, concrete gives excellent results. But concrete is a coming material and with more experience on the part of the architect in designing to suit the material and also with more experience and skill on the part of the man who handles it, in time, doubtless concrete will be freely used in constructing buildings of real artistic merit.

In what has been said this far, I have tried to define architecture, and to enunciate and illustrate its fundamental principles.

Architecture has been defined as the art of building in such a way as to meet the requirements of utility and beauty, and we have seen to a limited extent how these requirements are met; we have further seen that the underlying fundamental principles are structural and have examined illustrations of historic buildings embodying these principles.

During the time that I have been speaking of these various historic buildings, many of them very ancient, I doubt not some of my hearers have been wondering why it seemed necessary to examine these older buildings to the apparent neglect of others more modern and up-to-date.

From one point of view my supposed critics are correct, for unless we can make some practical use of our knowledge of the architecture of the past, it is well nigh useless.

Let me try to explain.

In describing the properties of electricity, it is not uncommon to compare it with the flow of water in pipes. In much the same way, and for the same purpose, architecture is likened to language.

Each language has its own peculiar structural form with its own idioms and vocabulary; if we speak the English language correctly, we must construe our sentences in accordance with its established principles, and use its idioms and the words that belong to its vocabulary in accordance with their accepted meanings.

If, on the other hand, we speak another language, as for example German, we employ a language of different construction and with other idioms and another vocabulary.

To speak the English or any other language in a manner acceptable to educated persons, we must conform with its structural principles, obey the established rules, and use the forms of speech which have gained the approval of those best qualified to judge.

If we do otherwise, we fail to express ourselves clearly, and show ourselves uneducated. If we employ words not sanctioned by good usage, we are guilty of using slang.

With architecture we have shown that each historic style is based on the use of a definite structural principle, and if we had gone further, we would have found that certain structural forms, mouldings and other details are identified with each style, and that certain kinds of ornament and decoration are most appropriate to it.

These architectural styles are used by architects as the basis of their designs.

Again, some one may object, and ask why employ any particular architectural style, why employ forms, details and ornament of more or less ancient origin, why not be original and devise new forms and new methods of your own?

Apply the same criticism to the English language. Refuse to use the language in accordance with its recognized structural forms; refuse to employ its idioms and its vocabulary, and try to invent new forms of expression and new words, and what is the result? An unintelligible collection of words and no words that have little or no meaning to the person who hears them, and which convey but an indefinite and hazy expression of the ideas of the person who uttered them.

On the other hand, if we employ the language in accordance with the best usage and with accuracy, and use its vocabulary correctly, and as is indicated in a good standard dictionary, we may convey to the minds of our friends the best thoughts of which we are capable with great accuracy, in the form of simple prose, or in a more imaginative and poetical form if our minds are so ordered. The great power and beauty of both thought and expression of which the language is capable is shown in the poems of a Wordsworth, a Browning, or a Tennyson.

We have outlined the possibilities of literary composition; so, too in architectural composition, by complying with the underlying requirements of good construction in a given style and by the use of a vocabulary of forms, details, and ornament appropriate to the style, derived, it may be, from older forms but adapted to modern requirements in the same way that a language is, we may produce modern buildings adapted to all the modern utilitarian requirements and at the same time full of meaning and interest to those capable of understanding them, and of a very high degree of beauty and artistic excellence, if the designer, like the poet, is capable of producing them.

THE ONTARIO BOARD OF HEALTH EXPERIMENTAL PLANT.

F. H. CHESNUT, B.A.Sc., '07
Engineer in Charge

At the present time when so much is being said, and justly, regarding the conservation of the vast natural resources of this country and province, the question of Public Health should not be entirely lost sight of. Surely the good health of our citizens is one of the greatest, if not the greatest, resource with which this fair country has been blessed. It must be admitted, even by the most shallow thinkers, that a country populated by a healthy race, not only tends to be better morally and spiritually, but will undoubtedly be the better able to develop those many natural resources which the Creator has placed at its disposal.

The question then arises, have we not in Canada ideal conditions for promoting health; if so, why worry over such questions as Public Health? The question is very pertinent. Yes, we have almost ideal conditions, or rather the close observer would say, we *had* ideal conditions and in some places these conditions have improved and in others they have deteriorated.

The next question is, what are these improper conditions, and what is their origin? The answer is, carelessness or ignorance have brought about unsanitary conditions of living. In explanation of this statement probably a short sketch of the rising of a nation would not be out of place, and would apply in general to our country as well as to any other.

The tribe or embrio nation divided itself into villages, each village disposing of its household wastes in a pit or oftentimes on the surface of the ground. When conditions became too bad and the senses of the inhabitants became tortured to the extreme the whole village packed up and moved to a new camp. This nomadic life soon became impossible, due to the increase of population. As soon as permanent villages became the only possible way of living we find records of terrible plagues which exterminated whole countrysides, and as the population of the country became denser and great manufactories were established the streams and lakes became so foully contaminated as to be nothing more than open sewers, and the nation became shaken to its core by epidemics of water-borne diseases.

The reader will readily see that the foregoing is nothing more than the life history of England up to about the year 1800.

Well, but you say, we have no such conditions in this country. No, but our present generation will see such conditions unless there is a concerted move in the direction of cleaner waterways and more regard on the part of the individual citizen, for the good health of his fellow being. What town in Ontario hesitates to dump its sewage and factory wastes into the nearest stream or river without even taking the trouble to find whether the town a mile or so down stream is going to be injured or not? There are few who hesitate, for to hesitate would mean ruin from the financial standpoint, so they say. Is this justice, that one town should be required to purify the sewage of another? You will say, and rightly, that the up stream town may dispose of its sewage in such a way as to not in any way affect the lower town; but that the people of this latter town would not feel safe in drinking the unpurified stream water on accocunt of contaminating features along its flow, which they or anyone else would be powerless to prevent. The evident answer is this: it costs much less to purify comparatively pure water than water directly contaminated by sewage, also from the esthetic point of view the nuisance caused by sewage is not to be desired.

To my certain knowledge a number of such conditions already exist in this province and still the health authorities are powerless to prevent their existence. And why are the health authorities powerless? Because the laws which govern sanitary conditions are inadequate and antiquated and the enforcing of such laws as do exist is in no way supported by public sentiment. But where do such laws originate? In the legislature, you say. Not at all. The people make the laws, and if the people make the laws it is the business, yes the duty, of every citizen, who realizes that better sanitary conditions are to be desired and can be had, to help to educate his neighbor to better ideals.

Surely prevention is better than cure. It is said that one Eastern nation pays its doctors so much per annum to keep its people well. When one gets sick the doctor's salary stops forthwith. Could we not follow this example by paying our sanitarians to keep us well?

What we want is better and purer water supplies. Pure water is one of the most essential things to human existence. Every community is willing to pay a small amount more per gallon for pure milk; but how many of these same communities are willing to add .0005 cents per gallon or .05 cents to their per capita daily supply of water, and get in return the cheapest and most useful commodity we have?

Let us assume then, that pure water is to be desired. How may it be obtained? By a consideration of the following general requirements:

(a) Look to the source of supply. If it be a lake or river which is liable to contamination due to sewage from towns in the district, either obtain a new and better source of supply or remove the cause of pollution, if not entirely at least so that the dilution which the sewage or waste receives is sufficient to make direct pollution of the water supply infrequent or remote.

(b) Having removed all apparent sources of pollution, the question should not then be considered completely solved, for even the best inspected water supplies show pollution at times.

(c) Finally, in a word, obtain the best possible water supply and purify it by the best known method.

The Ontario Government has seen fit to establish and maintain an experimental plant at Stanley Park in this city, with the following objects in view:

(1) The education of the general public to a more enlightened view of the questions of sanitation, in particular with regard to pure water supplies.

(2) The graphic demonstration to the general public of the possibilities in the different well-established processes of water purification and sewage disposal.

(3) The endeavor to discover new methods of water purification and sewage disposal, or to improve existing methods.

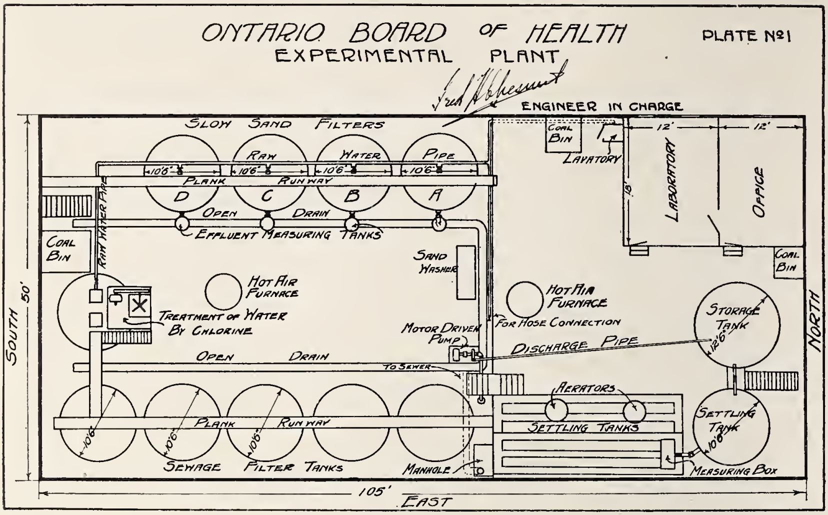
Description of Plant.

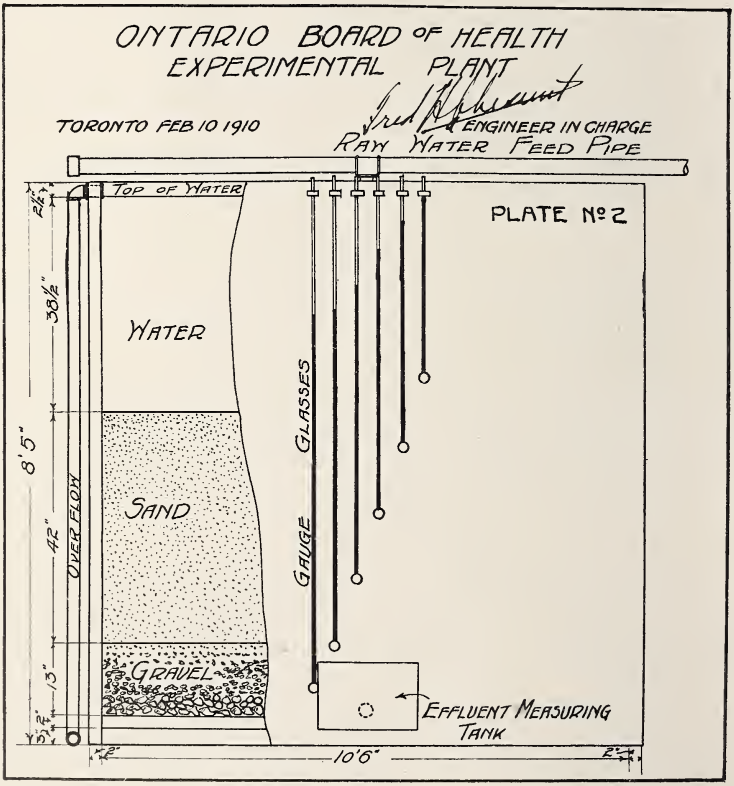
The plant is situated at the northern extremity of Stanley Park on Clifford Street. The building (105′ x 50′) is constructed of a timber framework covered with corrugated iron and lined inside with building paper. The main floor, on which are situated the tanks (see Plate 1) is some eight feet below the level of the ground outside, while the remainder of the floor space is at ground level. At the northwest corner are situated the office and laboratory. The work done is divided into two main divisions—Water Purification and Sewage Disposal.

Water Purification.

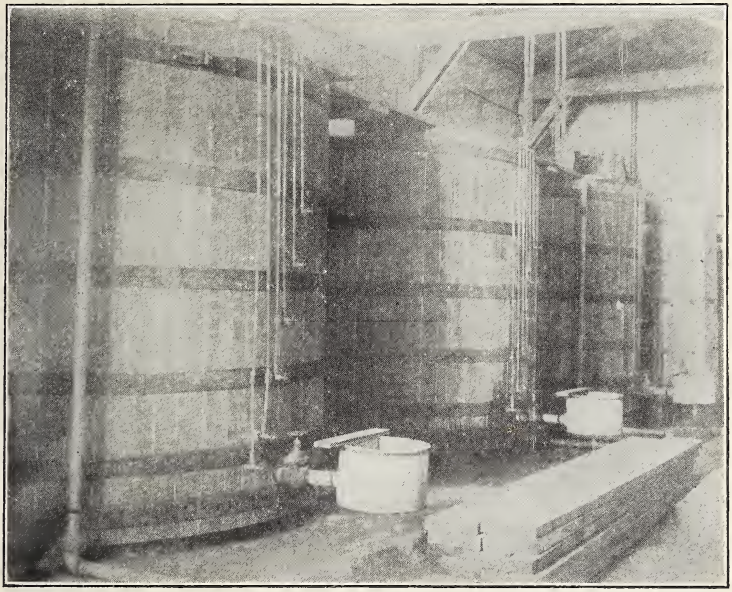
(a) *Slow Sand Filters.*

On the west side are seen the four slow sand filters for the filtration of raw or city tap water. Each of these tanks (see Plate 2) is circular and of the wooden stave type, eight feet high and ten feet six inches in diameter, having a surface filtering area of one five-hundredth acre. In each tank is placed 13 inches of gravel graded from 6-inch stones at the bottom to very fine material where it comes in contact with the sand. Over this is placed 3½ feet of sand having an effective size of .265 milli-


ONTARIO BOARD OF HEALTH
EXPERIMENTAL PLANT
PLATE No1
ENGINEER IN CHARGE
SLOW SAND FILTERS
RAW WATER PIPE
10'6"
10'6"
10'6"
10'6"
PLANK RUNWAY
D
C
B
A
OPEN DRAIN
EFFLUENT MEASURING TANKS
COAL BIN
RAW WATER PIPE
HOT AIR FURNACE
TREATMENT OF WATER BY CHLORINE
SAND WASHER
MOTOR DRIVEN PUMP
OPEN DRAIN
TO SEWER
COAL BIN
LAVATORY
12'
12'
18'
LABORATORY
OFFICE
COAL BIN
HOT AIR FURNACE
FOR HOSE CONNECTION
DISCHARGE PIPE
STORAGE TANK
12'6"
AERATORS
SETTLING TANKS
SETTLING TANK
10'6"
MEASURING BOX
PLANK RUNWAY
10'6"
10'6"
10'6"
SEWAGE FILTER TANKS
MANHOLE
SOUTH 50'
NORTH
105'
EAST


ONTARIO BOARD OF HEALTH
EXPERIMENTAL PLANT
TORONTO FEB 10 1910
ENGINEER IN CHARGE
RAW WATER FEED PIPE
TOP OF WATER
PLATE No 2
2½"
38½"
8'5"
42"
13"
2"
5½"
WATER
SAND
GRAVEL
OVER FLOW
GAUGE GLASSES
EFFLUENT MEASURING TANK
2"
10'6"
2"

meters and a uniformity coefficient of 2.056, the whole of this sand and gravel being carefully washed before being placed in the tank. The graded gravel is used as a support to the sand, keeping it from being washed out with the effluent. Each tank is provided with loss of head gauges, which consist of metal tubes running horizontally and radially from the centre to the sides of the tank and terminating on the outside and at right angles in glass tubes. These are placed at different levels and therefore the loss of head for several depths may be noted; the difference between each successive reading being the loss of head due to the friction of the sand in the vertical distance between the gauges. The discharge from each tank is measured in a measuring box, which contains several orifices, each of which under a fixed head gives a fixed and known discharge.



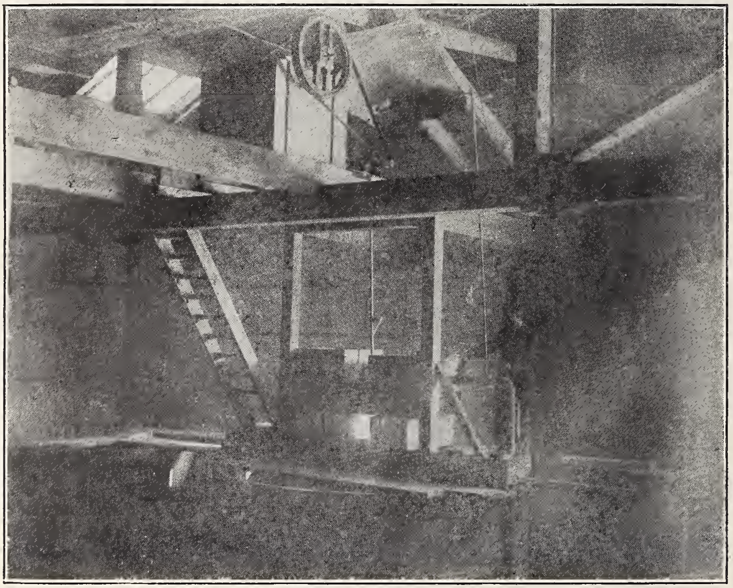
Slow Sand Filters

In operating the filters the raw water (city water) is run on the bed and in most cases allowed to stand for an hour. The effluent valve is then opened sufficiently to give the required discharge. As is well known, a "blanket" begins to form on the filtering surface at once, consisting of the suspended matters removed from the water as it passes through. It is this blanket which does the greatest part of the work in filtering. However, each grain of sand below the surface becomes coated with a jelly-like substance to which bacteria and other suspended matters readily cling. The exact amount of purification which takes place below the surface is unknown, but it is believed to be sufficient to warrant the placing of 3½ feet of sand instead of a few inches, which would be sufficient if the whole of the purification took place on the surface.

The first object aimed at in the operation of these slow sand filters was to obtain data which would establish the best rate at which Toronto or Lake Ontario water may be filtered, having in mind minimum cost of plant and cost of operation and maximum efficiency from a biological standpoint.

With this in view the tanks designated *A, B, C* and *D* were started on September 15th, 1909, at the following rates: Tank *A,* 20,000,000 gals. per acre per day. Tank *B,* 15,000,000 gals. per acre per day. Tank *C,* 10,000,000 gals. per acre per day. Tank *D,* 5,000,000 gals. per acre per day.

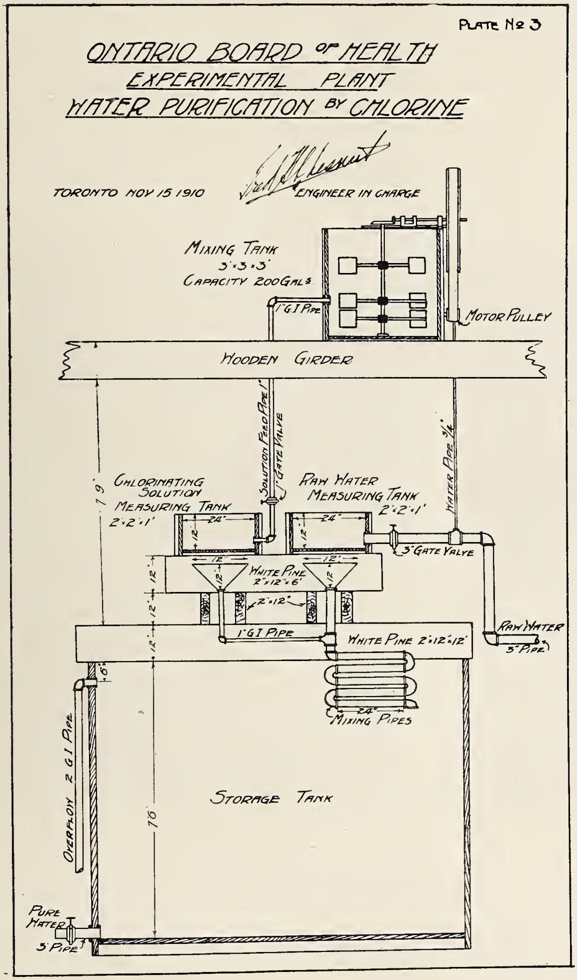
While the tanks have been run a sufficient length of time to give a fair idea of what the final results will be, it has not been thought advisable to make any statement in this regard as only a broad knowledge of what slow sand filters will do for Lake Ontario water can be reached by averages based on considerable data regarding "length of run," "discharge during run," "bacterial efficiency," etc. It may be said, however, without fear of correction, that slow sand filters will give the citizens of any town using Lake Ontario water, a good water, both from esthetic and biological standpoints.



Water Purification by Chlorine

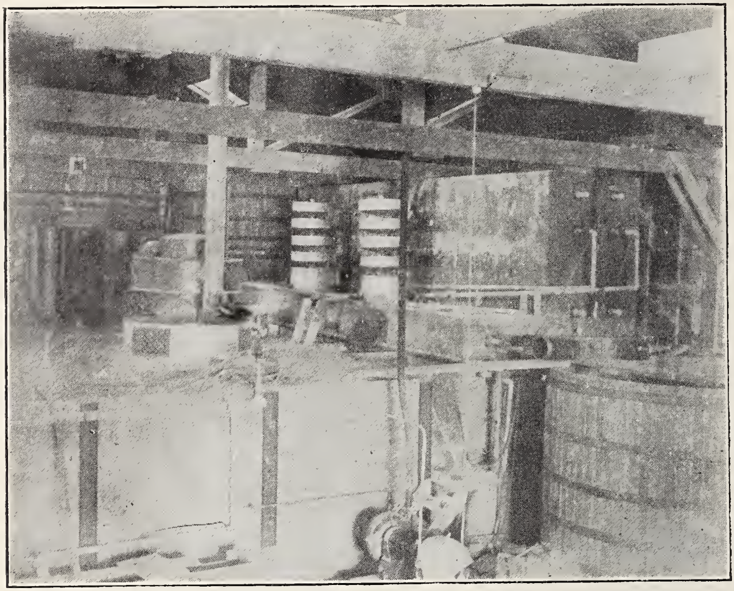
(b) *Water Purification by Chlorine.*

Dr. J. W. Leal, of Boonton, N.J., has installed a plant at that town which purifies the total water supply (40 million gallons per day) of Jersey City by the addition of small quantities of "bleach" to the raw water, without previous filtration of any kind. This treatment gave in many instances a sterile water and at all times a reasonably pure water (i.e., comparable with slow sand filter effluents) and at the cost of 14 cents per million gallons.



With the object of attempting to repeat this performance a plant of this nature has been constructed and has just been put in operation at the Experimental Plant.

From Plate No. 3 the general layout may be seen. The raw water enters the Raw Water Measuring Tank through a 3-inch pipe where the quantity flowing per hour is measured by means of a sliding orifice equipped with a graduated operating screw. Chloride of lime ("bleach") is mixed with a definite per centage (by weight) of water in the Mixing Tank, which is kept constantly stirred by a mixing device operated by a motor. The solution of chloride of lime then flows to the Chlorinating Solution Measuring Tank through a one-inch pipe and is there measured by the same method as the raw water. The chlorinating solution is added in such proportions so that a definite quantity of "available chlorine" is added to a definite quantity of water, both by weight. As will be seen the raw water and the chlorinating solution are caught in funnels and come together at the two inch to one inch tee connection. They are then well mixed in the system of return bend piping and fall into the tank below, where different storages may be given depending on the flow of raw water and on the height of the adjustable overflow.



Sewage Disposal Equipment

It is to be expected that there may be some difficulty in treating raw water by this method, due to the high turbidities frequently found. However, a roughing filter or a mechanical filter can readily be installed and used to give preliminary treatment before being "finished" by the chlorine process.

Full results of the operation of this plant will be published later.

Sewage Disposal

Owing to the unfortunate circumstance of a poor pumping installation it has been found impossible to raise the sewage from the 7½ foot sewer which runs under the building. The construction of a new manhole has just been completed and it is hoped that a plentiful supply of sewage will be obtained at an early date.

The fact of having no sewage has prevented the operation of such plant and apparatus as we have at present in position, and the possible prospect of a limited supply of sewage has prevented extensive planning of future work.

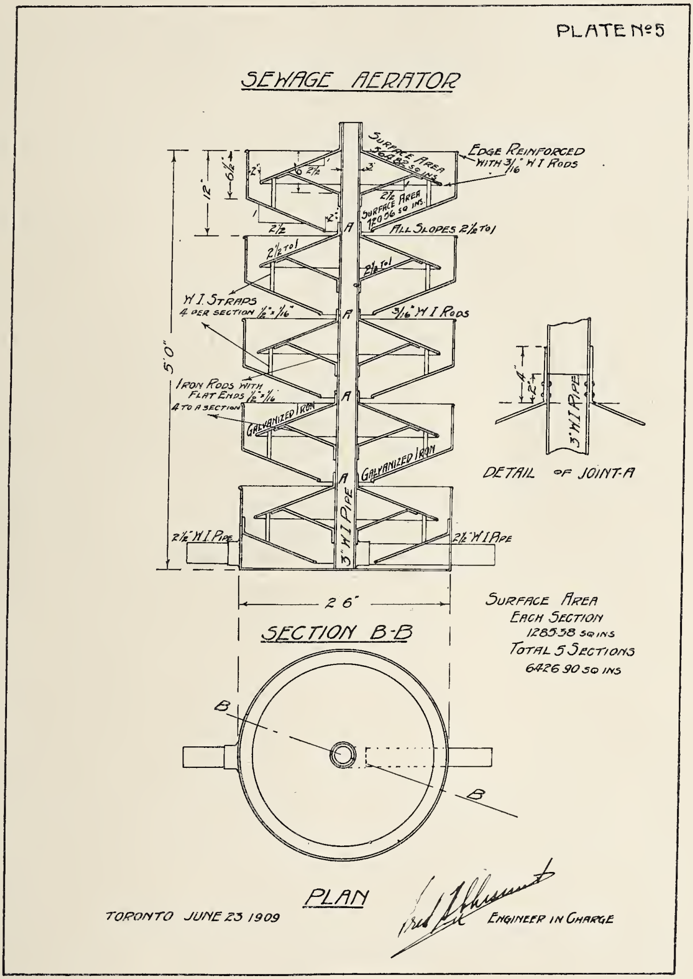


PLATE Nº 5

SEWAGE AERATOR

SURFACE AREA
EACH SECTION
1285.38 SQ INS
TOTAL 5 SECTIONS
6426.90 SQ INS

TORONTO JUNE 23 1909

ENGINEER IN CHARGE

As will be seen from Plate No. 1, the sewage is lifted by an electrically driven centrifugal pump, of 150 gallons per minute capacity, some 40 feet from the Garrison Creek sewer to a storage tank which is equipped with a float apparatus which throws out the motor when the level of the sewage in the tank reaches a certain required height.

The storage tank is connected to a settling tank by a 2½-inch pipe. From this settling tank the sewage is led into a measuring box, which rests on the top of the concrete settling tanks No. 1A and No. 1B. This measuring tank is equipped with brass orifices which are of such a size as to discharge sufficient quantities of sewage to give different rates of storage in the settling tanks, thus for one hour storage an orifice is used which discharges 1665 U. S. gallons per hour, which is the capacity of the concrete settling tanks used.

The sewage having been measured as described it is subject to protracted settling action for different periods of time and to aeration in aerators of the form shown in Plate 5.

The object of the layout just described is to determine the best rates at which settling tanks may be run, with aeration or without. The effluents from these tanks will be for the present run into the sewer, but later will be treated by the several different methods of filtration or to disinfection or sterilization.

The visible accomplishments which the plant shows, at the present time, are not in any way a measure of the time, labor and thought which has been expended on it. It is believed that the future will justify, in the concrete form of valuable data obtained, the money invested in this undertaking. We have done our best in an attempt to accomplish the objects aimed at and it is hoped that the citizens of Ontario will show more interest in the work which is being done by visiting the Experimental Plant and becoming acquainted with our work.

REINFORCED CONCRETE COLUMNS.

PETER GILLESPIE, B.A.Sc.
Lecturer in Applied Mechanics

The exact function performed by steel reinforcement in concrete columns, whether in the form of longitudinals or as hoops or spirals, has been the subject of much speculation and investigation. The behavior of the composite material under stress has not been and is not now satisfactorily understood. Do the steel and the concrete deform together in accordance with the classical assumption to that effect? Are there initial stresses in the metal (and also therefore in the concrete) due to a tendency to contract while setting? Does the presence of the steel affect significantly or at all, the elastic properties of the concrete which immediately surrounds it? Is the use of reinforcing metal, either as longitudinals or as hoops, an efficient and economical method of strengthening compression members? These and other questions that might be asked have been for theorists, an excuse for evasive hypotheses, and for investigators, a stimulus to investigation. In the discussion of efficiency and economy, a knowledge of the elastic and other properties of the materials employed is of prime importance. An ability to interpret the geometrical features of the stress-strain curve is a part of this knowledge, and is therefore very essential.

In Figure 1, the stress-strain curves for two concrete prisms are shown, the data having been obtained from "Tests of Metals" for 1904. The upper curve is for a 1:1 cement and sand mortar of ultimate crushing strength, 6,940 lbs. per sq. in. The lower is for a 1:2:4 cement, sand and gravel mixture which failed at 1,700 lbs. per sq. in. It will be observed that while the former continues straight, up to a stress of 2,500 lbs. per sq. in., the latter deflects almost from the start. That the former is at the outset, almost twice as steep as the latter will be interpreted as meaning that the modulus of elasticity of the richer concrete is nearly twice as great as that of the poorer. That there would be a permanent "set" for relatively small stresses in the case of the latter would be anticipated. As might also be expected, a much closer approach to complete recovery was realized in the other instance after even moderately large stresses.

When two dissimilar materials deform together, it is usually assumed that they take stresses in proportion to their relative rigidities. If, for example, the steel in the longitudinal reinforcing of concrete columns be ten times as rigid as the surrounding concrete, its stress for a given deformation will be ten times that of the concrete. Experiments conducted on columns of concrete of the grade ordinarily manufactured and reinforced in this manner show that the stresses in the steel, accompanying stresses in concrete of such intensity as is commonly specified, are very much lower than good practice will endorse or economy recommend. In the accompanying table are given some data taken from Tests of Metals for 1904. In parallel columns are shown simultaneous values of stress in concrete and in steel longitudinals in compression members having from .97 to 2.09 per cent. of reinforcing.

Simultaneous Stresses in Concrete and Steel.

Mixture—variable.
Percentage of metal in longitudinals—.97 to 2.09.

Test No.	Mixture	Average Stress, lbs. per sq. in.	Steel Stress, lbs. per sq. in.	Concrete Stress, lbs. per sq. in.	Steel Stress. / Concrete Stress.	Ultimate Strength, lbs. per sq. in.
1613	1 :1 :2	600	3,540	556	6.4	2,890
1612	1 :2 :3	600	6,360	516	12.3	2,010
1582	1 :2 :4	600	5,040	557	9.0	2,180
1581	1 :2 :4	600	5,520	549	10.1	1,990
1584	1 :2 :4	600	4,320	527	8.2	2,830
1579	1 :2 :4	600	3,780	532	7.1	2,760
1610	1 :2 :4	600	5,220	532	9.8	1,820
1616	1 :2 :4	600	9,060	476	19.0	2,095
1608	1 :3 :6	600	11,100	446	24.9	1,370
1617	1 :3 :6	600	4,860	516	9.4	2,290
Average			6,000	530	11.6	

From this table, it is seen that the average stress existing in steel longitudinals in columns carrying 600 lbs. per sq. in. over the gross area was only 6,000 lbs. per sq. in. In structural and bridge work, working stresses at least twice this would not be considered excessive. It is undoubtedly true that metal is sometimes employed in structures for emergency purposes, and ordinarily may sustain stresses which are very small indeed, or absent altogether. In the case of concrete columns, this is partly true. To take care of bending stresses due to eccentric loading, or to possible inequalities in the concrete, longitudinal rods are necessary; still if the working stresses in them could be increased somewhat past the limit given in the above table, it could be felt that more of the advantages of the use of the metal were being realized, particularly since, even when stressed to the maximum which good practice favors, it carries a load in compression at about twice the cost of concrete.

By employing a better grade of concrete, thus permitting the utilization of higher working stresses, a partial remedy is secured. An improvement in quality is, however, accompanied by a marked increase in the elastic modulus as well as in the ultimate strength as is indicated in Figs. 1 and 2, the latter being a typical stress graph for a plain 1:1 concrete of age three months, plotted from a test made by the writer. The aggregate was a hard trap rock, with the fine crusher dust screened out, the size of aggregate varying from ¼ to ¾ in. The member was first stressed up to 2,200 pounds per square inch when the load was released. The magnitude of the "set" is almost insignificant, it being observed that the second curve is plotted from a new origin. The prolonged straightness of the curve is one of its most noticeable features. The increase in stiffness which

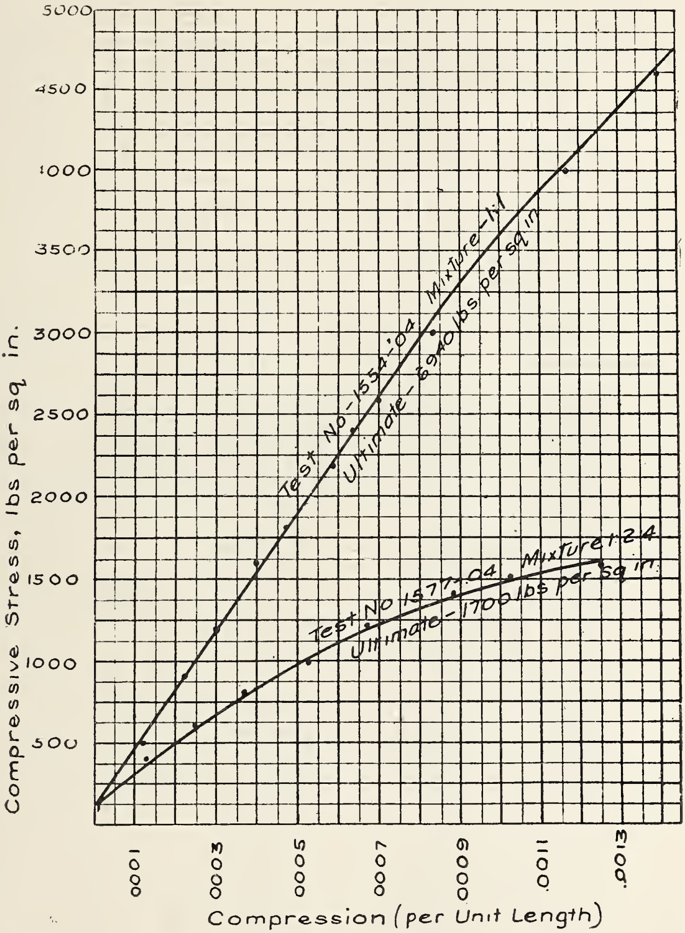


Fig. 1.—Curve showing the behavior of typical rich and lean mixtures under compressive stress

occurs whenever the quality of the concrete is improved, will mean a reduction in the stiffness ratio for the two materials, so that the increase in the steel stress due to the employment of a richer mixture, is not as great as might at first be supposed.

Below are given the results of a few compression tests made

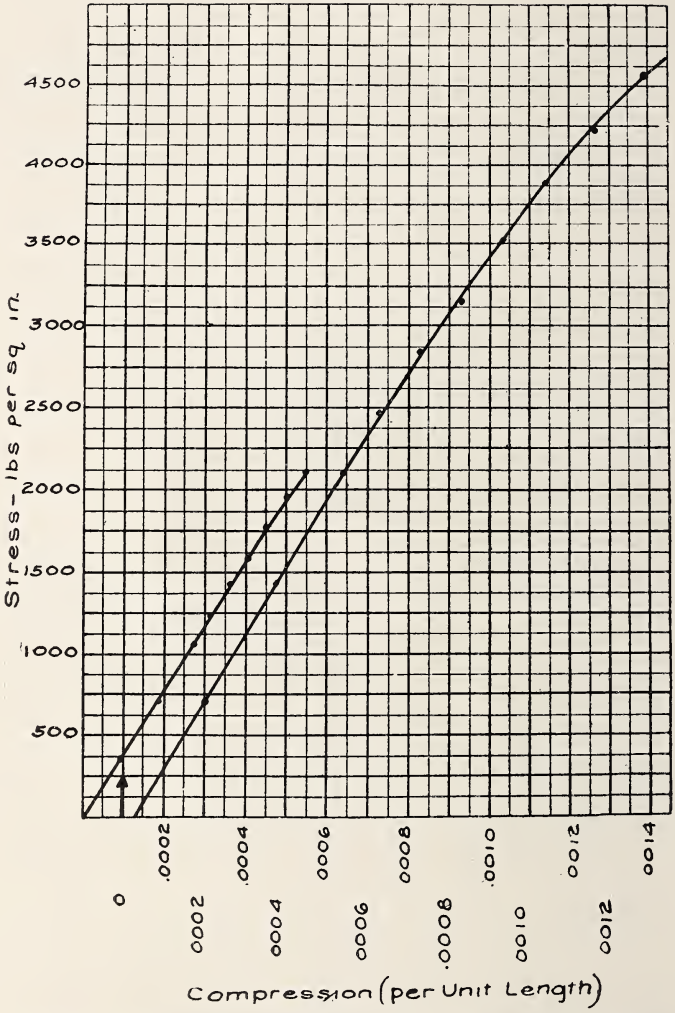


Fig. 2.—Curve showing the behavior of a 1:1 plain concrete under compressive stress

by the writer on columns of this grade of concrete. The specimens were 6 inches in diameter and 21 inches long.

Compression Tests on Short Columns.

Mixture—1 :1.

Age—6 months.

Specimen No.	Crushing Strength, lbs. per sq. in.
A	4,900
B	5,975
C	5,150
D	6,160
E	4,120
F	5,480
Average—	5,300

As the average strength is well over 5,000 lbs. per sq. in., it would seem that a working stress of 1,250 lbs. per sq. in, is not excessive.

To determine the manner in which such material will behave

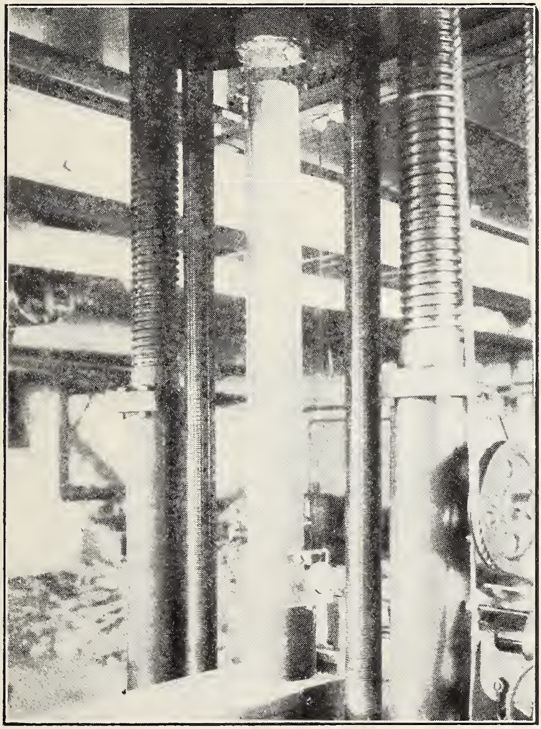


Fig. 3—Column with longitudinal reinforcement under test

in combination with steel, longitudinally placed, a number of columns were constructed and tested. Nine determinations of the modulus of elasticity for this concrete plain, gave an average value of 3,900,000 lbs. per sq. in., with the smallest value 4 per cent. lower, and the largest 4½ per cent. higher than the mean of all. Eight determinations of the elastic modulus in columns, reinforced with from .88 per cent. to 4.42 per cent. of steel, gave an average value of 3,600,000 lbs. per sq. in., showing that apparently the concrete is less rigid in the reinforced column than it is in the plain. In the latter case, the smallest value was 13 per cent. less, and the greatest, 11 per cent. more than the mean of all. The subjoined table shows in a few representative cases, the magnitude of the stress in the longitudinal reinforcement accompanying a stress of 1,250 lbs. per sq. in. in the concrete.

Simultaneous Stresses in Concrete and Steel Longitudinals.

Mixture—1:1.

Percentage of metal—.88 to 4.42.

Designation.	Stress in Concrete, lbs. per sq. in.	Stress in Steel, lbs. per sq. in.	$\frac{\text{Steel Stress.}}{\text{Concrete Stress.}}$
M	1,250	9,300	7.4
J	1,250	9,600	7.7
H	1,250	10,500	8.4
N	1,250	10,500	8.4
Q	1,250	12,000	9.6
R	1,250	10,800	8.6
O	1,250	10,500	8.4
P	1,250	10,500	8.4
Average—	1,250	10,400	8.4

On account of the increased working stress in the concrete, the average stress in the steel is substantially greater. The attainment of such stresses, rendered possible through the employment of a better grade of concrete, must be considered a step toward the economical use of steel in concrete columns.

Another matter of some consequence is the amount of "set" taken by the concrete after the stress is relieved. The most satisfactory materials for the purpose of the engineer are those which have for moderate stresses, the power of perfect recovery. Of concrete, as ordinarily manufactured, this can scarcely be said. It will be observed in the table below, that the average "set" for the rich concrete after a stress of 2,000 lbs. per sq. in. is approximately half as great as that of the poorer grade after a stress of half the magnitude. The data was taken somewhat at random from the report of the Watertown Arsenal for 1904, but is believed to be fairly representative of the two grades of material.

Table Showing the Amount of "Set" after the Release of Stresses in Two Grades of Concrete. Specimens all 12 Inches Long.

After 2,000 lbs. per sq. in.			After 1,000 lbs. per. sq. in.		
Mixture.	"Set", ins.	Ult. Strength, lbs. per sq. in.	Mixture.	"Set", ins.	Ult. Strength, lbs. per sq. in.
1 : 1	.0006	6,940	1 : 2 : 4	.0028	1,210
1 : 1	.0013	4,800	1 : 2 4	.0020	1,700
1 : 1	.0014	4,360	1 : 2 : 4	.0010	1,480
1 : 1	.0004	6,400	1 : 2 : 3	.0012	1,680
Average	.0009			.0017	

The function of hoops in compression numbers is to resist the lateral expansion which accompanies longitudinal compression due to load. For most materials, there is a more or less constant ratio between the lateral and the longitudinal strain. This is known ordinarily as Poisson's ratio, and for most materials of construction is about 1/3 or 1/4. Let us assume a concrete column reinforced with hoops and with longitudinal rods. When it is stressed by loading, a longitudinal shortening takes place which sets up stresses in both steel and concrete, the ratio between them being the ratio of their relative rigidities. If the hoops were absent, a lateral expansion would have taken place which, per unit of diameter, would be only a fraction of the aforementioned shortening per unit of length. The hoops reduce this to some extent (otherwise they would not serve their purpose), and consequently the unit deformation in them must be of even smaller extent. From this it is manifest that hoop stress will be very much less than the compressive stress carried at the same time by the longitudinal rods, and if some misgivings are had as to the wisdom of employing longitudinal steel in columns, certainly greater doubt might be entertained regarding the use of hoops. For while the fabrication of hooped reinforcement is usually more expensive than where longitudinal rods are used, the safeguard against bending due to eccentric loads and defective materials locally, is very inadequately afforded.

In the hooped columns, the tests on which are referred to below, a 1:1 mixture of small size trap rock and cement was used. The hoops were welded from steel flats and were of two thicknesses, .05 and .12 inches. The quantity of metal relative to the core within the hoops varied from .024 to .057. No longitudinal metal was employed save three strips of thin hoop iron that were employed as spacers for the hoops. In order to measure the stresses in the hoops, certain of the rings were left exposed, partly or completely, and to these, mirror extensometers were attached. Longitudinal deformations were measured by means of compressometers fixed to a gauge length of about 50 inches. In the curves of Figs. 4 and 5 an opportunity to see the manner in which the steel stress varies with the compressive stress in the concrete is afforded. In every case, as the concrete was subjected to higher compressive stresses, a tendency on the part of the curve to deflect downward manifested itself. In some cases, the curve became parallel with the axis of steel stress. This would indicate that the concrete under high compressive stresses, had reached a stage of partial plasticity within the hoops. The fact that on release of load after heavy stressing, the extensometers did not usually completely recover, would indicate that this apparent tendency to flow had left the steel in a state of residual tension, since usually the steel stress had not even approached the elastic limit. In Fig. 5, the continued increase in steel stress under a constant load is shown.

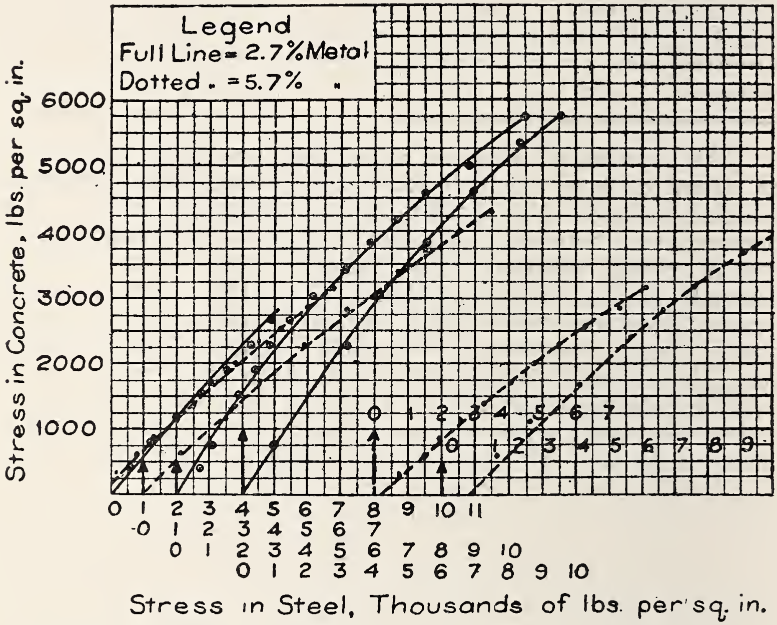


Fig. 4.—Curve showing the ratio of steel stress to axial compressive stress in hooped concrete, mixture 1:1.

From purely theoretical considerations if the elastic properties of the materials and the quantity of hooping present are known, it is possible to establish a simple relation between the compressive stress in the concrete and the accompanying stress in the encircling bands. In the evolution of the equation which follows, the stiffness ratio for this material was assumed to be 9. A number of determinations of Poisson's ratio gave ¼ for an

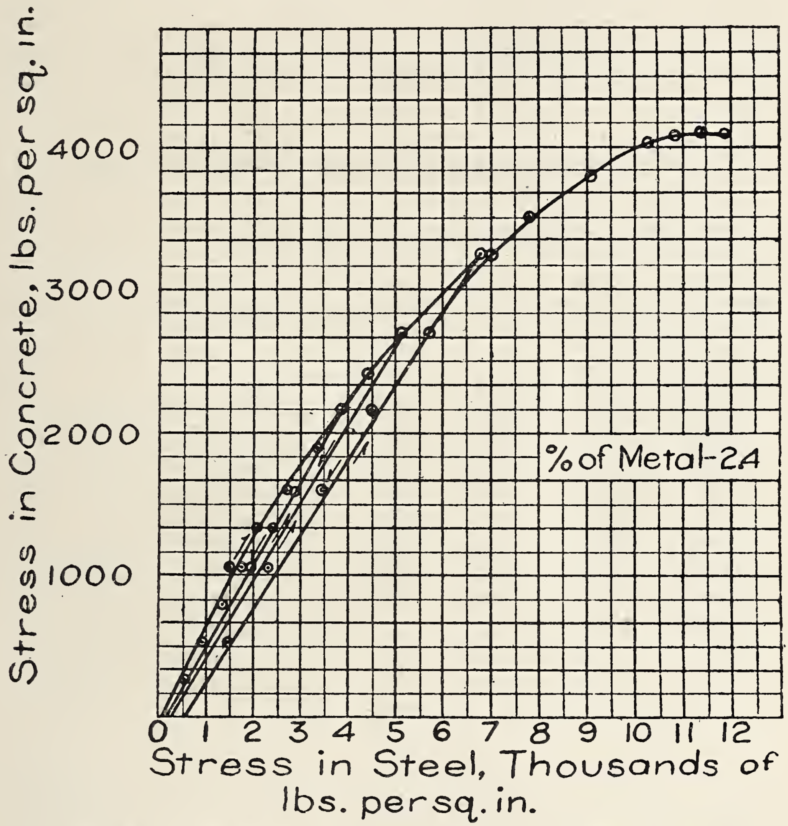


Fig. 5.—Curve showing the behavior of 1:1 hooped concrete repeated compressive stresses.

average value. For these materials, it can be shown that

$$\frac{f_s}{f_c} = \frac{9}{4 + \frac{9}{2}p}$$

where f_s is stress in steel bands, f_c is axial compressive stress in the concrete and p is the ratio of metal to concrete within the bands. Since p is usually small with respect to the other numbers involved, it follows that the usual changes which p might undergo do not affect the ratio $\frac{f_s}{f_c}$ in a very conspicuous way. In Fig. 6, the manner in which this ratio changes consequent on variation of p is shown. The points plotted adjacent to the curve show to what extent the theoretic investigation agrees with the results of experiment. In the following table are given a few simultaneous values of hoop stress and compressive stress in concrete. The figures are representative of a somewhat large number of determinations and broadly speaking, show, as is indicated on Figs. 4, 5 and 6, that for the materials employed, the hoop stress is approximately twice that in the concrete.

Simultaneous Stresses in Concrete and Steel Hoops.

Mixture—1:1.

Percentage of metal in hoops—2.4 to 5.7.

Concrete Stresses, lbs. per sq. in.	Hoop Stresses, lbs. per sq. in.	p.	$\frac{\text{Steel Stresses.}}{\text{Concrete Stresses.}}$	State of hoop.
2,400	5,500	.057	2.28	Partially exposed.
3,000	7,000	.024	2.30	Completely exposed.
1,900	4,300	.057	2.26	Partially exposed.
2,300	5,000	.057	2.18	Partially exposed.
2,000	4,700	.057	2.34	Partially exposed.
3,000	6,000	.057	2.00	Partially exposed.
3,250	4,000	.057	1.23	Completely exposed.
2,600	5,000	.024	1.92	Partially exposed.
2,300	5,000	.027	2.17	Partially exposed.
2,800	5,000	.024	1.77	Completely exposed.
2,750	5,000	.027	1.82	Completely exposed.
Average—			2.02	

Tests made by Professor Talbot in 1907 on hooped concrete columns using a 1:2:4 mixture showed that the ultimate strength was increased about 570 lbs. per sq. in. for each per cent. of hooping employed. Similarly, tests made at the Watertown Arsenal in 1906 show that one per cent. of metal in the form of hoops increased the strength of the member to the extent of 1,020 lbs. per sq. in. Professor Withey, in 1909, reported that for each per cent. of metal employed in the form of spiral reinforcing, the increase in ultimate strength on an average was 1,320 lbs. per sq. in. for 1:2:4 concrete. In most cases, the strength of the columns tested by the writer exceeded the capacity of the testing machine employed. In one instance, where the column had 2.4 per cent. of steel in the form of hoops, the ultimate strength was 7,660 pds. per sq. in. This, it will be observed, is equivalent to an increase in strength over plain concrete of 1,000 pds. per sq. in. for each per cent. of metal. The manner of failure is shown in Fig. 8. From these and other tests which might be cited, a generous allowance for hooping would be 1,000 lbs. per sq. in. gross strength for each per cent. of metal employed. Tests conducted on hooped columns reinforced also with longitudinal rods indicate that greater efficiency is obtained from the rods than when employed without the hoops.

A comparison of costs between the rich mixture concrete column, carrying light longitudinal reinforcement, and a hooped structure of estimated equivalent ultimate strength is interesting. The materials laid down have been assumed to cost as follows:

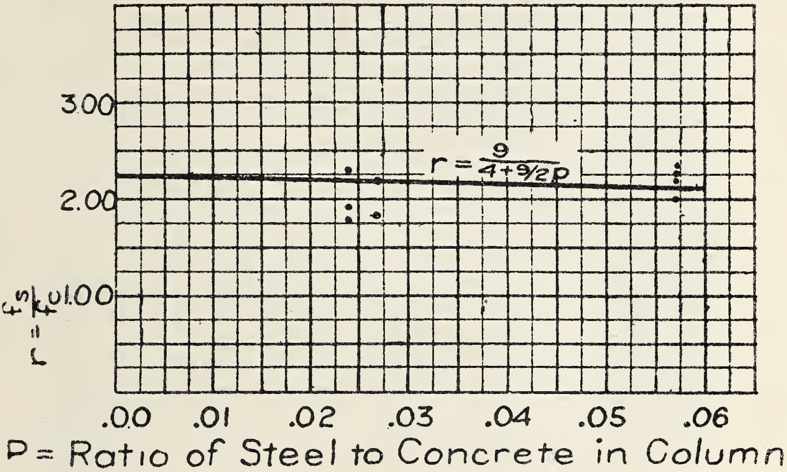


Fig. 6.—Curve showing the theoretic variation of the ratio $\frac{f_s}{f_c}$ with change in the percentage of metal in concrete of mixture 1:1.

Cement, $1.50 per barrel.
Aggregate, $2 per cubic yard.
Sand, $1 per cubic yard.
Plain reinforcing, 3c. per lb.
Hooping, fabricated, 5½c. per lb.

For a 1:1 cement and rock mixture, the cost per cubic yard will be:

Cement	$ 8.10
Rock	1.58
Labor	2.00
Plain steel, ½ per cent.	2.03
Total	$13.71

Since the metal is added chiefly as emergency material, it will not be figured in the ultimate strength which will be taken at 5,000 lbs. per sq. in. A 1:2:4 concrete (the ultimate strength of which plain may be assumed at 2,000 lbs. per sq. in.) will be rendered equivalent in strength to the 1:1 mixture by the use of 3 per cent. of hooping metal. The cost per cubic yard will then be:

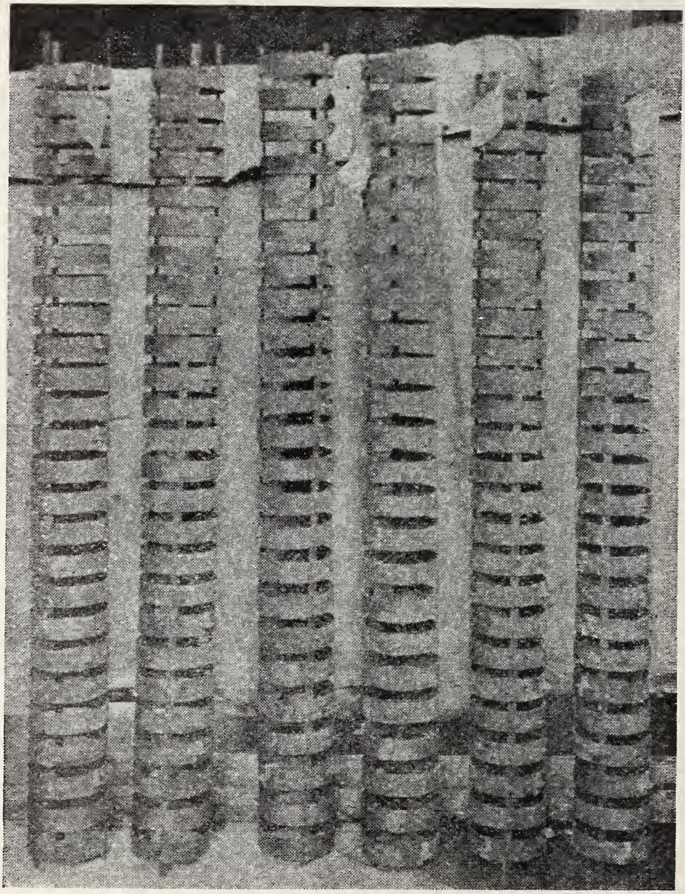


Fig. 7.—Hoop Reinforcement ready to place in forms

Cement	$ 2.53
Rock	2.00
Sand	.50
Steel hoops	22.28
Labor	2.00
Total	$29.31

In addition to the greater cost, this column will not possess the stiffness and probably not the margin of safety against bending stresses which are found in the cheaper column.

In order to compare the areas of three different types of columns, and their cost per foot of length, it will be assumed that a 10-storey building with dead and live floor loads at 200 lbs. per sq. foot, and a roof load of 100 lbs. per sq. foot is to be constructed. Assume also square floor bays of 15-ft. to a side.

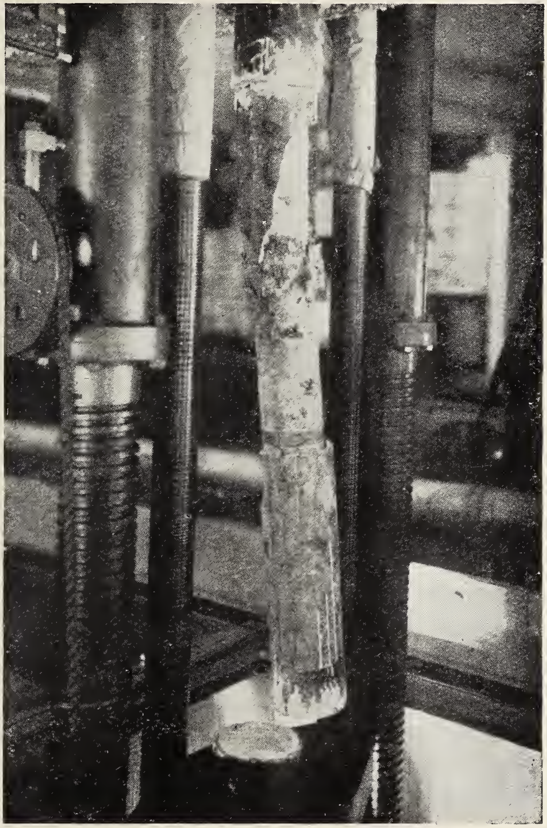


Fig. 8.—Failure of a hooped concrete column; three of the hoops nearest the centre have burst.

It will be seen that the load sustained by a column on the ground floor will be 427,500 lbs. This may be carried:

(a) By a structural steel column.
(b) By a column of the poorer grade of concrete.
(c) By a column of the richer mixture.

A reference to the Carnegie handbook, p. 141, shows that a steel column consisting of two 10-in. channels and two ⅞-in.

plates will be adequate. This column weighs 121 lbs. per running foot. The cost per foot of height will be:

Steel at 5c. per lb.	$6.05
Fireproofing, 2-in. thick	.58
Total	$6.63

A 1:2:4 concrete column with 1 per cent. of longitudinal metal will be figured at 450 lbs. per sq. in. for the concrete, and 450 × 15 = 6,750 lbs. per sq. in. for the steel. The average stress will, therefore, be 450 (1 + .14) = 513 lbs. per sq. in. The gross area required will be 427,500 ÷ 513 = 833 sq. inches. Hence a column 29 inches square will be adequate. Allowing one inch additional for fireproofing, we have a column 30 inches square, the cost of which, per foot of height, would be:

Concrete, including 1 per cent. steel and labor	$2.55
Forms	.46
Total	$3.01

The third method employs a 1:1 mixture, the working stress on which will be taken as 1,250 lbs. per sq. in. The area required will be 427,500 ÷ 1,250 = 342 sq. inches. This is the area of a square of 18.5 inches to the side. Allowing 1½ inches for fireproofing, we obtain a column 20 inches square, the cost of which per foot of height with ½ per cent. of longitudinal steel would be:

Concrete, including ½ per cent. of steel and labor	$1.30
Forms	.32
Total	$1.62

The areas of the cross-sections in the three cases are:

(a) 1.8 sq. ft.
(b) 6.3 sq. ft.
(c) 2.8 sq. ft.

It is thus seen that the difference between the smallest cross-section and the largest is 4.5 sq. ft., an item of considerable importance in districts where the rental of floor space is high. On the other hand, the difference in cross-sectional area between the most expensive method of carrying the load, and the cheapest is 1.0 sq. ft. Having regard then to the fact that the rich mixture column costs only one-fourth as much as the steel structure, there would seem to be a good deal to be said in favor of the stronger mixture.

The writer desires to state that of the experimental work referred to above, part was conducted in the Testing Laboratory of McGill University in Montreal, and part in the Laboratory of Applied Mechanics in the University of Toronto, the former being done under the general supervision of Professor E. Brown, of the Department of Civil Engineering.

The consideration of the reader is invited to the following inferences to which an examination of the data at hand seems to lead. Since the experimental evidence supporting these conclusions is, in the opinion of the writer, scarcely extensive enough upon which to base broad generalizations, they are not advanced as being final and conclusive.

1. The rich mixture is more uniform in its elastic properties than the lean mixture, and for proportionate stresses, the permanent set is likely to be very much less. The parabolic feature of the stress-strain curve is also less noticeable.

2. The employment of a rich mixture in columns permits of the more economic stressing of the steel longitudinals. It is very probable that a strength equal to that obtained by the use of a 1:1 mixture can be secured by the careful grading of the aggregate, and the use of less cement.

3. The experiments cited indicate that, for the materials employed, the stress in the steel hoops was approximately twice the axial compressive stress in the concrete core. The steel is consequently not economically employed.

4. Theoretically and experimentally, the variation in the relation of steel stress to axial compressive stress does not vary greatly with variation in the percentage of metal.

5. A given ultimate strength can be more cheaply secured by a rich mixture lightly reinforced by longitudinals than by the utilization of hooping. The former also secures greater rigidity and safety against bending.

6. For equal safe loads on columns, the lean mixture is probably intermediate in cost between the steel column and the rich mixture lightly reinforced by longitudinals, the latter being the cheapest.

7. The cross-sectional area of the steel column is least for a given loading, and the lean mixture greatest. The difference between the cross-sectional areas of a steel fireproofed column and a rich mixture concrete column is the least of all.

BUILDING ACOUSTICS.

G. R. ANDERSON, M.A.

It is a rather remarkable fact that notwithstanding the paramount importance of good acoustics in a public building, there should be a very large proportion of our halls and churches whose acoustic properties are notoriously bad. The reason for this may be found in the fact that architects in general have not given the matter very serious consideration, being content to plan the building for convenience or artistic effect and, if they gave a thought to the acoustics, it was merely to abide by certain ancient superstitions and hope for the best. The inevitable result of such a hit-and-miss method has naturally been a large number of failures.

One of the commonest fallacies which has gained acceptance even among the best architects is that if a certain building possesses good acoustic properties, then all other buildings constructed on the same general plan will also possess good acoustics. This is tantamount to saying that *form* is the only factor determining the final result, whereas it is but one of several and not in general the most important.

After the architect has completed his work and the builders have faithfully followed the plans and specifications, it very often happens that although the general effect is entirely satisfactory, yet the audience cannot distinctly hear the speaker or the music and thus the main purpose of the auditorium is not fulfilled. In such a case the hall is either left in this unsatisfactory state and is a constant source of annoyance to both speakers and audience, or attempts are made to remedy the mistakes that should never have occurred. Now if the architect has not the knowledge necessary to design the hall with a view to securing good audition, it can scarcely be expected that he will be able to remedy the trouble afterwards, so that attempts in this direction are quite often failures and leave the building no better than before.

When the acoustics of a building are found to be unsatisfactory an attempt to improve matters is sometimes made by raising the platform on which the speaker stands. This is often done in churches and in case of a high vaulted ceiling results in a large proportion of the volume of sound being lost to the congregation. Such a plan, although not generally productive of much improvement, has at least a rational basis, namely that of allowing a clear path from the speaker to the audience.

There is, however, another practice in vogue, the origin of which seems as obscure as the reason for employing it; this is the plan of stretching wires or strings across the room. The practice is a very common one and scores of beautiful halls and churches in Canada and the United States have been disfigured through faith in this hoary superstition, which has not a vestige of reason to support it.

A third method frequently employed is that of hanging curtains or draperies at the back of the stage or about the hall. Such a plan is often effective but loose draperies are very objectionable on account of the dust and germs that they are liable to collect and, at least in the case of music, they are often apt to make matters worse rather than better.

The main factors governing the audition of a hall or church are:

1. Its dimensions compared to its seating accommodation.
2. Its form in reference to certain details.
3. The materials employed in its construction.
4. The arrangement of the heating and ventilation.

Given control of these and the acoustics of the hall is a matter of exact calculation as much as is the strength of its roof and walls.

Excessive reverberation is one of the chief troubles occurring in public buildings and this defect is more pronounced in modern buildings on account of the extensive use of structural steel and concrete; nevertheless it is entirely feasible to so proportion the building and distribute the materials of interior construction that the results will be satisfactory and this without detriment to the building in any way.

The writer was recently called on to examine and if possible improve on the acoustics of the Margaret Eaton School of Literature and Expression in this city. The public hall of this school was an oblong room of about 70,000 cubic feet, having a low stage at one end and a gallery at the other. The main floor seated 300 and the gallery 100 persons. The acoustics of this hall were so bad that musicians and speakers had almost invariably refused to appear there a second time, and the Principal and Board of Directors were most anxious to have anything done that would save the reputation of their auditorium. Tests on the empty room and also in the presence of an audience showed much too great a reverberation with a zone of maximum disturbance across the centre some six or eight feet wide; further, the residual sound of the note from a middle C organ pipe died away without alteration of pitch to the limit of audibility, indicating that there was neither reinforcement nor suppression of upper partials; this would have been almost self-evident from the form of the room and stage. In this hall the believer in the stretched wires had already been on the ground, for at the time that the writer was called to see it there existed a system of some eighty cords stretched from side to side, presenting a most unsightly appearance in an otherwise beautiful room. These were at once removed, the walls were deadened sufficiently to reduce the reverberation 25 per cent., when the acoustics were declared to be perfectly satisfactory and there have been no further complaints in regard to the hearing in any part of the hall.

Another example of a somewhat similar nature may be given, namely that of Knox Church, Spadina Avenue. In this case the plans had been submitted to the writer and calculations in advance of construction indicated that with some minor modifications the result would be satisfactory. These plans included a gallery on three sides of the auditorium, but the Building Committee, to reduce the cost, eliminated the two side portions of the gallery, thereby changing the amount of surface and the seating capacity. When the building was completed it was found that the acoustics were by no means satisfactory. The plan of raising the pulpit platform and of placing a sounding board over the speaker were both tried without marked improvement. Tests on the building gave a reverberation of about 20 per cent. over that calculated on the original plans. This has been reduced to normal value by panelling the two long side walls beneath the rail and the two inner walls of the transept, some 1,800 square feet in all, and the hearing is very satisfactory.

Other examples might be given but they would not indicate anything essentially different from those stated. The two cases mentioned show that it is entirely feasible to construct buildings in which the acoustics shall be satisfactory and also in some cases to remedy those that have been badly designed. Sound is a form of energy similar in many respects to light and heat, subject to the well established laws of reflection, refraction and absorption and if these laws are intelligently applied there need be no fear of the final result; but when such statements as are contained in the subjoined paragraph published in the newspapers of this city some three years ago, are given to the public apparently in good faith, it is not surprising that failures are as common as successes, for what more could be expected of men who would be responsible for the publication of such nonsense?

The paragraph refers to a well-known building just then completed: "The acoustic properties of the building are its special features. Any sound uttered upon the platform carries perfectly to any point in the auditorium. The glass in the dome is so set in the steel ribs as to prevent vibration, and the girders used in the construction are tuned to a pitch and adjusted to a fixed strain in order that the whole structure may be in tune."

PRACTICAL HINTS ON UNDERGROUND SURVEYING.

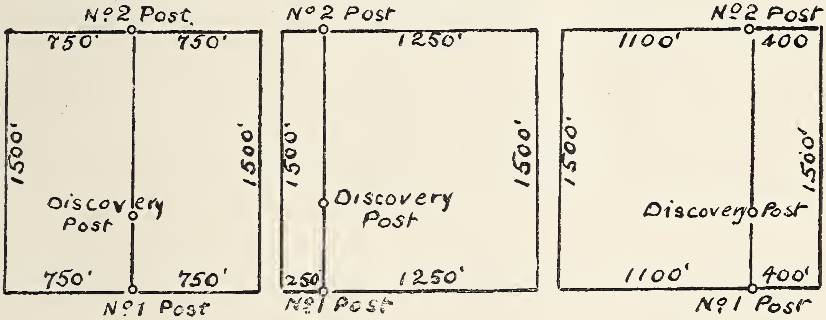
WM. A. O'FLYNN.

The first duty of a man on assuming the position of surveyor to a mining company is to check up the work of his predecessor provided the underground workings are not too extensive. In case the mine were entered by a long tunnel it would be best to make a complete resurvey, connecting it with the surface lines.

Then I would advise the boundary lines to be resurveyed and all corner posts located as the surveys of mining claims are not always paragons of perfection. This will give you the correct data for your maps.

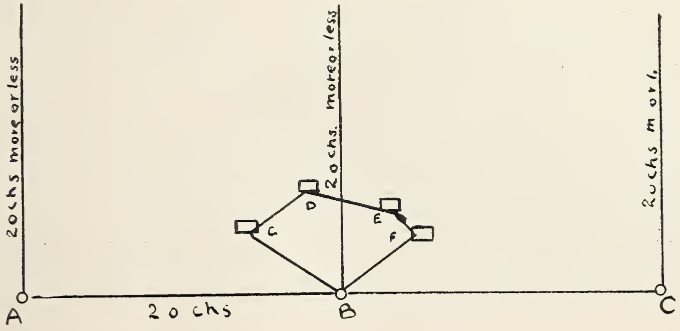
Familiarize yourself with the different systems of laying out mining claims, as they play an important part as to where you should start your survey to connect with the underground workings.

In British Columbia, Saskatchewan, Alberta and Northwest territories a quartz claim is laid out thus:



In this system connect up and tie in all your work to No. 1 post.

In Ontario in the surveyed districts owing to the system in vogue it would be best to start from one of the posts on the south boundary, e.g., suppose you had four shafts to connect, located thus:



In this system start from which ever post is nearest the shafts, i.e., B, and connect with a traverse survey tying in at B. You can assume your astronomical bearing from A B or get it by an observation. Assign the proper bearing to the respective lines, using latitudes and departures for plotting your work. If your latitudes and departures close correctly you know that your work has been correct and this will obviate the necessity for resurveying.

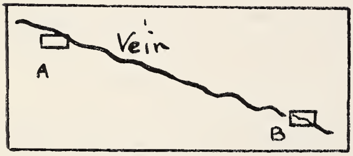
The reason for starting from the posts is that you will be able to see by your map the exact position of the workings so that they will not be encroaching on your neighbor's property nor he on yours and hence prevent litigation, which is not uncommon in mining. If such is the case there is always a resurvey by some O.L.S., P.L.S., or well-known surveyor of repute and the correctness of your work adds to your success. Never leave any loopholes.

There are five different methods for connecting the surface surveys with the underground workings.

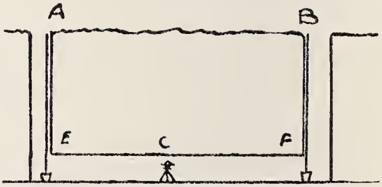
First by means of a slope or adit-level—When the underground workings are connected with the surface with an adit level or a slope, the surface survey is carried into the mine through this opening. Up to 50 deg. there is not much lifficulty other than the danger of slipping, but when the slope reaches 60 deg. your line of sight in most transits will strike the vernier plate, and then it becomes impracticable to continue the work without employing some indirect method. (See method No. 6.)

Second, by means of two shafts—When the shafts are vertical and can be connected by a straight line.

Example:



Plan
Fig 5



Elevation
Fig 6

First establish points at A and B in a straight line from your last hub if possible, if not, set up very near A or B, establish the further one, transit the telescope and establish the other. Reverse instrument and repeat the operation. Always check your work.

Then drop plumb lines down the shafts at A and B. For attaching your plumb line a piece of flat iron 14 in. x 1½ in. x ½ in. which can be fastened to the timbers and set in place by the transit is advisable.

The best material to use for a plumb line is fine piano wire and if you are surveying a deep shaft it is imperative to have it.

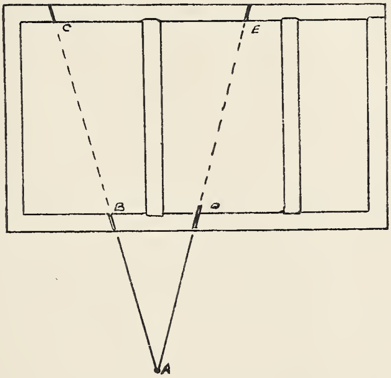
The plumb-bobs should weigh from 5 to 9 lbs., and in order to prevent the wire from breaking when lowering it is advisable to use a lighter weight to lower it with, say about 1 lb.

The bob is attached and placed in a tub or barrel of water, or oil, the latter being preferable if obtainable, so as to reduce the oscillation.

You then descend and set up the transit at C, Fig. 6, getting some one to stand behind one of the plumb lines and sight the instrument in line as correctly as possible. Then sight on A or B and transit the telescope. If the vertical cross hair is in line with the plumb line you must be in the straight line joining A and B, that is, provided your transit is in perfect adjustment, which it should always be in mine surveying; if not, move the transit by means of the moveable head in the necessary direction, then sight on A or B transit telescope and sight on forward plumb line, repeating the operation until you get in the straight line.

Then establish points in the roof at E and F, Fig. 6, or at a point which will be conveneint to start off your work. E and F will have the same bearing as A and B, and from E F you can commence your underground work.

Third, by means of four plumb lines.



This method is applicable in a double compartment shaft of which the above is a plan.

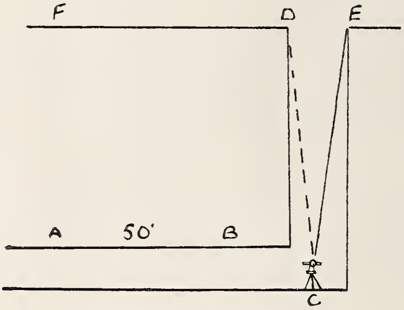
Establish the point A in some suitable place near the top of the shaft, taking care that the conditions underground will enable you to lay out the work below as above.

Then establish the points B, D, C and E, using the iron hanger. (See method No. 2.)

Measure and record distances AB, BC, AD, DE, BD and CE, also measure and record the angle E A C and check your readings by doubling the angle several times. Then drop the plumb lines as stated hereinbefore in method No. 2.

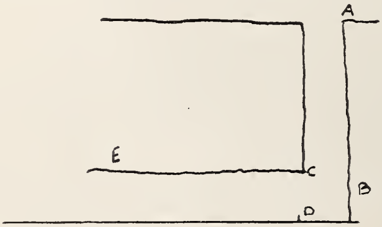
Care should be taken to see that the plumb lines hang full. Then check the distances BC, DE, CE and BD. Then by means of a straight edge placed as near as possible to the plumb lines B and C measure off BA and establish A, then do likewise at E and D. This will locate approximately the point of intersection A. A large block of wood is suitable to locate the point of intersection A. Two pieces of fine wire can also be used. Then set up the transit at A and measure the angle CAE and if it agrees with the angle observed on the surface you must be over the point of intersection A, if not, move the transit until you have by repeated trials obtained and agreed with the angle established on the surface. Then recheck all the distances AB, BC, AD, DE, BD and CE again. Now if all your measurements agree with the surface ones you have evidently carried down the azimuths of the lines AC and AE, and from these you can commence your survey by establishing fixed points at suitable places, in the roof.

Fourth, by means of a transit.



Put a spud in the roof at B and set the transit up in the middle of the shaft at C, and establish the point A by putting a spud or wooden plug in the roof and in the same straight line as CB, then by means of a prismatic eyepiece establish the points D and E, then go up on the surface and at a distance FD nearly equal to AC set up the transit in a straight line with DE. This having been accomplished, you can connect up with the surface survey.

Fifth, by means of an auxiliary telescope.



Set the transit up at A so that you can see vertically downwards and establish the points B in the timbers about 8 ft. from the ground point C in the roof and the point D directly under

C, then descend and set up at D. Lower the telescope and the cross hair out to be in line with a plumb line hung at B, then transit the telescope and establish a point at E and set up, then you hang another plumbob from C then E and B ought to be in the same straight line. These are checks which can be eliminated if the instrument is in perfect adjustment.

Sixth, a method for surveying down an inclined shaft greater than 60 deg.

Fig. G

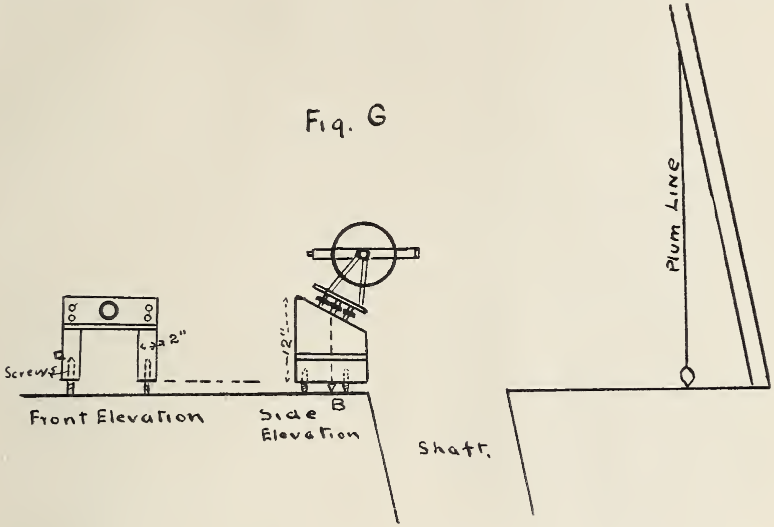
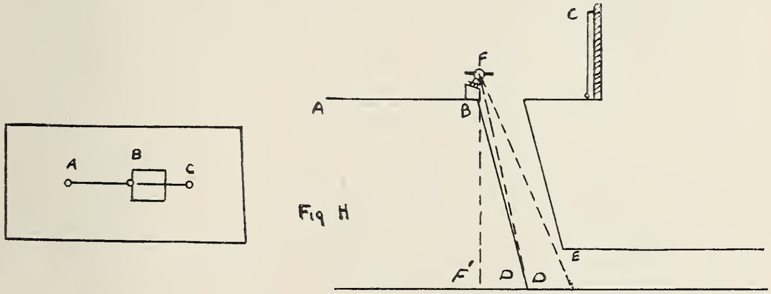


Fig H



Establish the point A and set transit up at that point, then establish the point B a few inches from the mouth of the shaft and the point C in the same straight line, and about 20 ft. above the ground or at such a height that the telescope of the transit will be elevated to an angle greater than 45 deg. From this point drop a plumb line. Then set up at B, using a device such as Fig. No. 9 shows, provided you have a transit which is placed in its box by means of screwing it on to a board. You can attach this board to two pieces of wood cut at an agle of about 25 deg. Having two screws on each piece which can be screwed up into the wood by means of pliers, so as to adjust the wood device and get it level, using a carpenter's level therefor. Then get approximately two levelling screws of the transit at right angles to the plumb line hung from C, and level up the bubble which will also be at right angles to C. Now sight on C and depress the telescope and if the transit is level in a line at right angles to C, and also the axis on which the telescope revolves, the vertical cross hair will follow the plumb line from the point C to the bob, if not you will have to shift the levelling screws and by trial obtain the aforesaid position. Now using plumb line from C as a foresight, establish point D in the timbers about ten feet off the ground and also the point E on the floor. Then level the telescope or see that the telescope is parallel to the horizontal plane. This can be done by means of the level directly under the telescope, and with the telescope in this position observe the angle on the vernier, then depress the telescope and observe the angle that FE makes with the horizontal and then by subtracting the angle observed when the telescope was in a horizontal position. You will have the exact angle of depression, also observe the angle that FD makes with the horizontal and proceed as before. Then subtract the angle the FE makes with the horizontal from the angle the FD makes with the horizontal and you will have the angle DFE which is required for solution of the triangle, and by subtracting the angle that F makes with the horizontal from 90 deg. you will obtain angle EFF^1. Now having solved the triangles you have the distance F^1E which, added to B plus the little distance that the centre F is from B, you have the exact chainage of E.

Then descend and set up, using tripod over point E and hang a plumb line from D and using it as a backsight you can continue your survey underground, or the tripod could be placed so as to give the transit the required tilt of about 25 deg. and I would suggest placing two levelling screws of the transit on line AB back from the mouth of the shaft and the other two at right angles to the line AB.

I would add that in mining a transit of low power is preferable on account of the short sight. It must always be in perfect adjustment, and it is absolutely necessary that all the work, i.e., distances and angles should be checked several times by the methods which are taught by the faculty. And when producing a line always reverse the telescope and always use as near as possible equal distances between stations. Now as to levels. When an engineer starts in a new proposition and has a number of shafts to sink and probably to connect hereafter, he must have correct levels so that he can have the drainage coming to which particular shaft that he desires, and thereby having a down grade for his ore which will enable the muckers to do more. Another economic value would be that he would not have to buy and install a pump, as occurs in some places and in Cobalt where the 150 level of one shaft is from 5 to 10 ft. different in elevation. It would also be advisable to establish a permanent bench mark.

OBITUARY.

Charles Goodfellow Milne, B.A.Sc., '93.

Charles Goodfellow Milne was born October 8th, 1870, at "Hillside," in the township of Scarborough, York County. He received his high school education at Markham and Whitby, and entered the School of Practical Science in 1889. In 1892 he graduated in the course of mechanical and electrical engineering, and took his B.A.Sc. degree the following year.

Charles Goodfellow Milne

At that time structural engineering offered him the most promising opening, and he spent several years in and around Pittsburg and Elmira at structural drafting. In 1895 he returned to Canada and became connected with the Hamilton Bridge Works Co., where, in a short time, he was made chief draftsman. He assumed the position of chief engineer of this company in 1901, which position he held at the time of his death.

His health had been poor for the last year or so, and in spite of a holiday trip to Panama in the spring, he was taken down with typhoid fever early in July, 1909. He never recovered from the effects of this attack, and died December 13th of the same year at the age of thirty-nine. He married in 1891, and leaves a widow and three daughters.

Of the many engineering works which were carried out under his direct supervision, perhaps the best known are the St. Maurice River railway bridge over the gorge at Shawinigan Falls, Que.; the Canadian Pacific viaduct at Parry Sound, Ont.; the Canadian Northern Railway bridge at Prince Albert; the head office of the Bank of Hamilton, Hamilton, Ontario; the Traders Bank Building, Toronto, Ontario; and the Grand Stand, Toronto Exhibition Grounds.

His ability as a structural engineer was equalled by his knowledge of electrical and mechanical branches. Probably his versatility is best shown in the plant of the Hamilton Bridge Works Co., of which practically every detail was designed by himself. His death cut short a career which was always a credit to his alma mater, and the profession, and which gave every promise of being a very brilliant one.

William E. Cole.

Born August 5th, 1883; deceased December 31st, 1909.

William Ernest Cole received his public school education at Lucasville. On completing this he attended Sarnia Collegiate Institute, where he secured a teacher's certificate. After attending model school at Sarnia he spent three years teaching public school in Sarnia township.

William E. Cole

Having decided to make engineering his life work, he registered at Toronto in the fall of 1905 in the department of Civil Engineering. During his college days he made many friends by his cordiality and unceasing good humor. He was an enthusiastic football player and a hearty supporter of all college athletics.

When he took a position on the Transcontinental Railway soon after graduating in 1908, he entered into the work with his characteristic enthusiasm and soon established for himself a record for rapid and accurate engineering work. He was rewarded by promotion and his prospects in the engineering field seemed very bright, but about the first of December, 1909, he contracted typhoid fever. He was taken to New Liskeard hospital where he received the best of care and medical attention. Having passed the crisis of the disease he was thought to be progressing favorably when he took a relapse which resulted in his death on the last day of the year.

The funeral was held from his home in Sarnia and the many floral tributes testified to the high esteem in which he was held by his friends there.

William J. Larkworthy.

Early in the summer of 1909, one of the most energetic and promising graduates of the Faculty of Applied Science and Engineering passed away in the person of William J. Larkworthy.

Mr. Larkworthy was born at Mitchell, Ont., in 1879, where he received his Public and High School education and where many busy and happy hours were spent as a boy indulging a pronounced taste for experiment and invention. All his pocket money went to purchase material for engines, boats, electric lights, telephones and a great variety of other mechanical and electrical contrivances in which he had an all-absorbing interest. It was but natural, therefore, that when the time came to choose his life-work, he should select electrical engineering and accordingly he entered the School of Practical Science at the age of eighteen. Ill-health compelled an absence of a year after two years of student life, but he returned and graduated with the class of 1903. A year of practical work with the Bell Telephone Company then followed, after which he took the post-graduate year, obtaining his degree in 1905. Those who were with him in the last days of the session of 1904-1905 will well remember the extraordinary energy which he gave to the project of forming the class into a permanent organization, and it is owing to him more than to anyone else that the arrangement was finally effected.

William J. Larkworthy

As soon as college days were over he began work in earnest with the Niagara Falls Hydraulic Power and Manufacturing

Co. with whom he spent over two years, engaged largely upon original investigations of the possibilities of the electric furnace in manufacturing processes. Following this he became president of the Electric Navigation Co. of Buffalo, but after three months his health failed and he was sent to Denver in the hope that recovery might be brought about. Unfortunately the desired result was not realized, and he was brought home to Mitchell, Ont., where after a year spent in a tent he finally passed away. To his classmates and all who came in contact with him there remains a pleasant memory of a buoyancy and optimism which were singularly well expressed in his student name—"Lark."

Wm. E. Elwell.

Born Nov. 13th, 1880; died Sept. 3rd, 1909.

Wm. E. Elwell, whose death occurred in Ottawa on Sept. 3rd of last year, was born in that city on November 13th, 1880, and was consequently in his 30th year. He was the son of Rev. Wm. Elwell, now of Chicago, Ill., a minister of the Catholic Apostolic faith.

Mr. Elwell entered the School of Practical Science in the fall of 1899, and graduated with the class of 1902. During his academic career he stood high among his fellows as a student. At the same time he took a prominent part in athletics, being very successful in upholding the honor of the University as a member of the Track Club. He was also a member of the "School" hockey club.

After graduating he went to New York, being employed with the New York Edison Co., but the inside work not being congenial he returned to Canada and entered the Topographical Surveys Branch of the Department of the Interior in October of 1905.

On Sept. 3rd, 1906, he married Miss Ida Thornton, of Whitevale, Ont. Needless to say, the taking away of one who in early manhood gave promise of such a useful future, has occasioned general regret among a wide circle of friends.

John C. P. Molesworth.

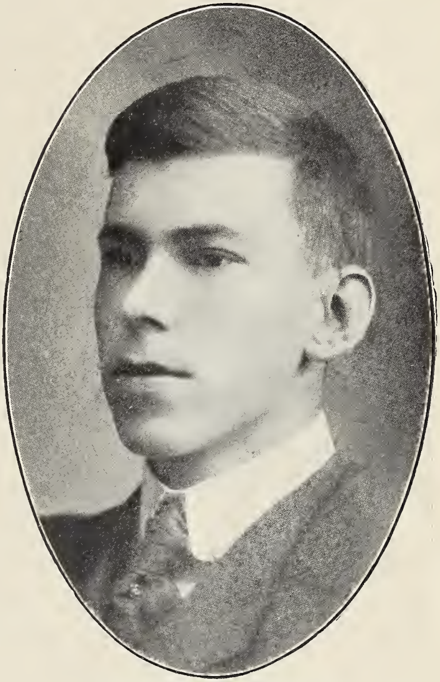
John C. P. Molesworth was born at Toronto, January 26th, 1888, received his preliminary education at the Model School, Toronto, and later obtained honor matriculation from Jarvis Street Collegiate Institute, entering the Faculty of Applied Science of Toronto University as a student in Architecture in

1905. The high character of work submitted by him may be recalled by referring to the class lists of his year. Each year he obtained Honor Standing in his work and in 1908 received the diploma with honors.

From the time of graduation till the time of his death he was identified with the firm of Chadwick & Beckett, architects, Toronto.

It is sufficient to mention the keen interest which he placed in athletics. As a member of the Argonaut Rowing Club, he availed himself of the privileges at his disposal for physical development. His interest, however, was divided with other sports than that mentioned, both at the University and at the club in Oakville.

During his University career he was a member of 2nd Field Company, Canadian Engineers, and later he identified himself with "K" Company, Q. O. R. In both these regiments he held non-commissioned rank and displayed live interest in their work.



John C. P. Molesworth

As a member of St. Luke's Church he showed an interest in the various institutions of the parish and it will be regretted that his opportunity for service has been cut off by an untimely accident.

His fellow graduates of 1908 maintain the fond recollection of one whose every manner was frank and true, showing no evidence of flattery to friends and possessing to an admirable degree the quality of reservation.

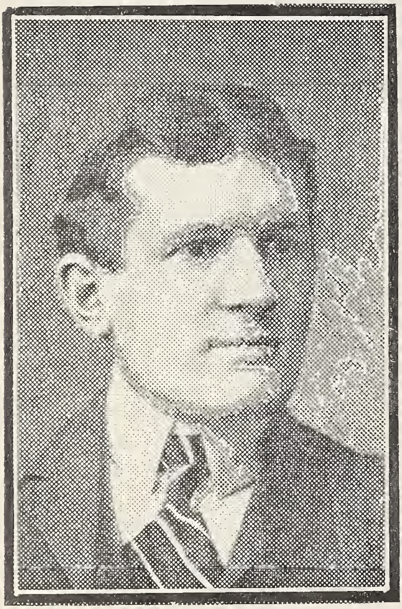
Though absent from our midst, his personality remains.

L. A. McLean.

We regret to have to record the death of L. A. McLean, B.A.Sc., '08, at Ottawa on February 14th, 1910, under the saddest of circumstances. During the vacation of his school course he was engaged on D.L.S. work and the high grade of his work, as told by all of those to whom he was assistant, promised great things for his future. All of those who knew McLean in his school course deeply regret his untimely death and his parents have the heart-felt sympathy of every School-man.

Stanislas Gagne.

On April 15th, news reached Toronto of a terrible accident in the construction camp of the Ha! Ha! Bay Railroad in Quebec. Additional interest was added by the fact that a Toronto man, Stanislas Gagne, was one of the victims. Details show that a remarkably large and premature dynamite explosion caused an immense landslide, which buried the construction camp at the foot of a hill, where the victims were sleeping.



Stanislas Gagne

Mr. Gagne was a partner of the firm of Gagne, Jennings & O'Brien, engineers and contractors. He was about thirty-one years of age. In 1901, he graduated from the School of Practical Science and at once became associated with the late W. T. Jennings, who considered him one of his cleverest engineers. He was Mr. Jenning's chief assistant in the Niagara Power construction work and became chief engineer of the right of way. After Mr. Jennings' death his son, Gordon T., joined Mr. Gagne and the firm had a great deal to do with the Toronto, Niagara & Western Railway. Mr. Gagne was also the designer of the Fort Erie and Buffalo bridge, and was associated with the Toronto Suburban Railway, the Vancouver, Victoria & Eastern Railway, and other projects.

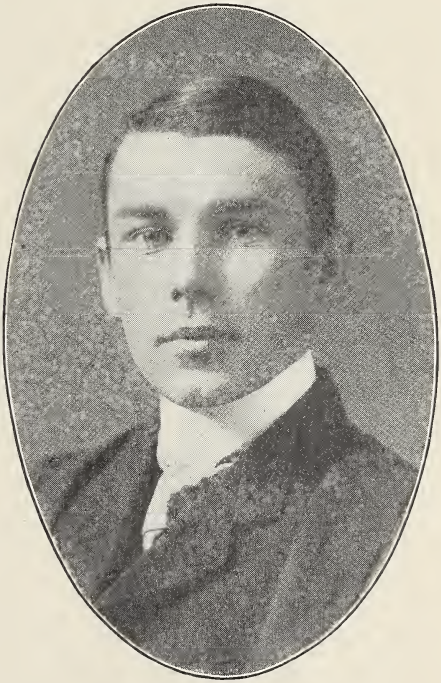
On obtaining the contract for the construction of the Ha! Ha! Bay Railroad, F. N. O'Brien joined the firm.

Mr. Gagne was one of the School's most loyal graduates and it was largely through his influence that such a number of French Canadians have in the last few years entered the University.

He was unmarried. His father, Francois Gagne, who is about sixty years old, lives at St. Joseph d'Alma, Quebec. The sympathy of all School men goes out to him and his in this their hour of affliction.

Milton Bates.

The unexpected death of Milton Bates at his home in Chatham, Ont., in November of last year came as a shock to a large circle of friends and acquaintances. He was of unusually robust constitution, but suffered from a relapse of typhoid fever which he contracted in the Cobalt country early in the fall. Mr. Bates was a graduate in Mining of the class of '06. He returned in 1907 to take his degree of Bachelor of Applied Science. Before entering the School, Mr. Bates had considerable experience in the copper mines of northern Michigan and during his summer vacations. He spent most of his time after graduating prospecting in Northern Ontario or with the firm of H. T. Routly & Co. as surveyor at Haileybury. Mr. Bates was of an unusual congenial disposition and made a host of friends for himself while taking his course at the University, and was one of the best known men of his year. His pluck and perseverance made all his undertakings successful and no doubt, had he been spared, he would have made a name for himself in the country.



Milton Bates

ADDRESS OF W. D. BLACK, RETIRING PRESIDENT OF ENGINEERING SOCIETY.

Gentlemen,—This is the last opportunity I shall have of addressing you as your president. I wish to thank each one of you for the personal support and consideration you have shown me during my term of office.

The past year has seen some important changes in the affairs of the Society and with your permission I will review some of the work which has been done.

The Supply Department has been completely revised by enlarging it and introducing a new business system, so that we now have a store, run on thoroughly business lines and kept open during all school hours. A permanent sales clerk was employed, a cash register purchased and an auditor employed to audit our books and introduce a new system of book-keeping so that we now have an absolute check on funds and stock.

Several new lines of goods have been handled this year, including a text-book by one of our lecturers. This marks a new epoch in our work and I think much better results could be obtained if each of our professors were to publish a text-book thoroughly covering his branch of our studies. The Engineering Society is now in a position financially to aid the lecturers in this work and thus do away with the multitudinous number of printed notes in pamphlet form, which has been advocated in the past.

The paid secretary, Mr. MacKenzie, resigns that position this spring. Under his editorship, our journal, "Applied Science," has been a credit to the Society and to the University. It forms a splendid link and tends to promote the most cordial relations between graduate and undergraduate. In the past the paid secretary has also been assistant registrar of the Faculty, but it has been thought better to employ one who could devote his time wholly to the interests of our Society and thus be in a position to relieve your Executive of much work. Mr. H. Irwin has been appointed to this position. Under him I feel that "Applied Science" will not depreciate and that the best interests of the Society will be advanced.

Our annual dinner was a success. At it we entertained eighty of the most prominent members of the Canadian Manufacturers' Association in an effort to bring about a closer relationship between the School and these captains of Canadian industries. That the attempt was to some extent successful was shown by the letters received from engineers and manufacturers expressing appreciation of our efforts and congratulating us on their success.

The papers read before the Society have been of great interest and the meetings well attended. It says much for the loyalty of our graduates to their Alma Mater and for their appreciation of the Engineering Society that two have come from New York, one from Montreal and one from Pittsburg at the expense of considerable time and money especially to address the Society and to give us the benefit of their experience.

The second vice-presidents have worked loyally and unselfishly for the welfare of their various sections. Good papers have been the rule and the excursions to various manufacturing establishments in the city, arranged by the vice-presidents, aided by members of the staff, have been attended with much profit.

The most cordial relations have existed between the students and the staff whom I have always found anxious to do everything possible for the advancement of the Society. Your thanks are especially due Dean Galbraith, Professor Wright and E. A. James, editor of the Canadian Engineer, who have aided your Executive to an extent perhaps not appreciated by you, in carrying out the undertakings of the Society.

One real grievance which I think we have is in the condition of our library which is more or less a joke as it exists at present. Most of the books contained in it are relics. The University is at present expending a great deal in a central library but apparently the need of modern engineering literature has been overlooked.

I have had reason to congratulate myself on the very able and strong Executive with whom I have been associated in carrying on the affairs of the Society. It has been a pleasure to work with them and to them belongs the credit of what has been accomplished this year. I recommend for your unstinted approbation the members of that Executive. I congratulate you on your choice for the coming year and feel confident that the best interests of our Society will be advanced under their administration.

In conclusion, gentlemen, let me thank you for the honor you have done me, and which it has always been my honest endeavor to merit.

I take great pleasure in presenting to you your president-elect for 1910-11, Mr. A. D. Campbell.

TREASURER'S REPORT

The finances of the Society are in a very healthy state, the balance sheet showing a surplus of two thousand eight hundred and sixty-two dollars and fifty-eight cents.

Applied Science, this, year, charging the Society for copies distributed to the undergraduates, more than paid for itself.

The supply department was under heavier expense this year, having a special clerk which enabled it to be kept open at all hours. A cash register has been installed at a cost of $175.00, and alterations made in the layout of the supply department at considerable expense.

The following is a summary of business of the year:—

Cash Account Summary.

To receipts from		
Applied Science	$1,286.81	
Supply Department	6,820.39	
Sundries	1,320.58	
Dinner	492.50	
		$9,920.28
By disbursements for		
Applied Science	$1,601.31	
Supply Department	6,477.27	
Sundries	723.54	
Dinner	764.82	
		$9,566.94
Balance cash as per cash book		$353.34
Undeposited cash	$ 28.50	
Pass book balance	380.87	
Outstanding checks		56.03
	$409.37	$409.37

BALANCE SHEET.

The following balance sheet shows the finances of the Society for the year ending March 31st, 1910:—

Assets.

Merchandise as per inventory	$1,839.84	
Cash register less 10 per cent. depreciation	157.50	
Accounts due Supply Department	60.80	
Accounts due Applied Science (advt.)	568.71	
Accounts due Applied Science (cuts)	43.00	
Sundry accounts	103.25	
Balance cash book	353.34	
		$3,126.44

Liabilities.

Accounts outstanding Applied Science	$ 263.96
Surplus	2,862.48
	$3,126.44

Surplus March 31st, 1910	$2,862.48
Surplus March 31st, 1909	2,040.66
Net gain for year	$ 821.82

Respectfully submitted,

F. V. MUNRO,

Treasurer.